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MINUTES AND PROCEEDINGS

of the

ARMY-NAVY-OSRD VISION COMMITTEE

TWELFTH MEETING - 12 JUNE 1945

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M I N U T E S A N D P R O C E E D I N G S

of the twelfth meeting of the

ARMY - NAVY - OSRD VISION COMMITTEE

12 June 1945

National Academy of Sciences
Washington, D. C.

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U. S. Armed Forces - NRC Vision
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ARMY - NAVY - OSRD VISION COMMITTEE

MINUTES

Twelfth Meeting
National Academy of Sciences
Washington, D. C.
1000, 12 June 1945

The following were present:

ARMY	AAF	(M)Major E. A. Pinson
		Lt. Col A. P. Gagge, Aero Medical Laboratory
		Lt. Col. P. R. McDonald, Air Surgeon's Office
		Capt. David W. Bishop, Air Surgeon's Office
		Dr. William O. Jenkins, Air Surgeon's Office
	AGF	Major L. O. Rostenberg, Requirements Section
	AGO	Lt. Charles P. Sparks, Personnel Research Section
	Ord	(A)Mr. John E. Darr
	SG	(M)Col. Derrick T. Vail
	WDLO	(M)Capt. Howard E. Clements
NAVY	BuAer	(A)Lt. Harry London
		Lt. (jg.) Virginia Withington, Instruments Branch
		Ens. Brian O'Brien, Jr., Equipment and Material Branch
	BuMed	(M)Capt. J. H. Korb
		(A)Lt. Comdr. R. H. Peckham
		Lt. Harry J. Older, Aviation Psychology Branch
		Dr. Franklyn D. Burger, Research Project X423
	BuOrd	(A)Lt. Nathan H. Pulling
		Lt. Ellsworth B. Cook, Harvard University
	BuPers	Lt. (jg.) Kenneth E. Clark, Enlisted Classification Section
	I C Bd	(M)Lt. Comdr. George W. Dyson
	NMRI	(CM)Dr. Harold F. Blum
		Lt. M. Bruce Fisher
	NRL	(M)Dr. E. O. Hulburt
		(A)Dr. Richard Tousey
	SONRD	(M)Lt. Comdr. H. Gordon Dyke
	SubBase	(M)Capt. C. W. Shilling
		(A)Lt. (jg) W. S. Verplanck
		Lt. Dean Farnsworth, Medical Research Department
		Lt. J. H. Sulzman, Medical Research Department
	MFRL	Ens. Sherman Ross, Medical Field Research Laboratory, Camp Lejeune
	NAS	Lt. Comdr. H. F. Cross, NAS, Patuxent River, Md.
		Lt. Comdr. Carl Pfaffman, NAS, Pensacola, Fla.
		Lt. Jean Welbaum, MCWR, NAS, Jacksonville, Fla.
		Lt. (jg.) Jesse Orlansky, NAS, Quonset Pt., R. I.
		Ens. Donald H. Kelly, NAS, Patuxent River, Md.

NAVY ORG Dr. E. S. Lamar, Operations Research Group

OSRD NDRC (M)Dr. Arthur C. Hardy
(M)Dr. Brian O'Brien
(CM)Dr. F. E. Wright
APP (M)Dr. H. K. Hartline
Dr. Dael Wolfle, Technical Aide
Dr. John L. Kennedy, Technical Aide
CMR (M)Dr. Walter R. Miles
(CM)Dr. Selig Hecht
OSRD (M)Dr. Donald G. Marquis

Dr. Morris S. Viteles, Committee on Selection and Training of Aircraft Pilots, NRC
Lt. Col. J. G. Dillane, RCAMC, N. D. H. Q., Ottawa
Wing Comdr. K. A. Evelyn, RCAF, Biophysics Laboratory, Montreal
Wing Comdr. S. R. C. Nelson, RAF Delegation

1. The chairman called for corrections or alterations in the Minutes and Proceedings of the eleventh meeting. There were no corrections.

2. Lt. Comdr. Peckham demonstrated an experimental model of the dichroic search filter described in the Proceedings of the eleventh meeting, pp. 65-72. 69* **

3. Col. Vail presented the report of the first meeting of the Subcommittee on Procedures and Standards for Visual Examinations, 8 May 1945, and asked for committee approval of the Instruction Manual for Testing Visual Acuity developed by Col. Vail and Lt. Farnsworth acting on subcommittee recommendation. After discussion of the manual, the committee

AGREED: that the manual should be revised at a second meeting of the subcommittee, 28 June 1945, in the light of comments from members of the committee and from Army and Navy activities which would be concerned in its adoption and use.

A summary report of the subcommittee meeting appears in the Proceedings. 13

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*Numbers at the right refer to pages in the Proceedings on which the full report or discussion is presented.

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4. Dr. E. S. Lamar reported further results of measures of the influence of size and asymmetry on contrast discrimination. 15

5. Lt. Older discussed briefly the new Navy film, "Night Vision for Airmen", which was demonstrated to the Committee.

6. Dr. O'Brien demonstrated a hand-held model of the NDRC sun-obscuring device described in the <u>Proceedings</u> of the eighth meeting, pp. 27-30.

7. Dr. Hecht presented the report of the Subcommittee on Design and Use of Binoculars (<u>Minutes</u>, eleventh meeting, p. 11, item 9). A proposed design for field tests of various hand-held and mounted binocular instruments to be carried out with the participation of Vision Committee members and interested individuals at the Submarine Base, New London, during August and September, was discussed. After determining that the results of the proposed binocular tests would be immediately useful, the Committee 20

VOTED: that the project be approved.

Subcommittee formulation of answers to questions proposed by Comdr. Ballard concerning design of binoculars and telescopes (Nos. 3-10, <u>Proceedings</u>) were considered. The Committee

VOTED: that the subcommittee report be accepted, printed in the <u>Proceedings</u> for further careful study, and considered for final action at the next meeting.

The following detailed presentations accompany the report of the subcommittee:

A. Outline of proposed tests of optical instruments for night use. 27

B. Calculations involved in the answers to questions 5, 7, and 8. Dr. Hartline 30

8. Dr. Miles presented the report of the first meeting of of the Subcommittee on Sunglasses, 11 June 1945. After discussion, the committee 40

VOTED: that the following recommendations of the Subcommittee on sunglasses be adopted:

1. It is recommended that the services adopt the same requirements for transmission in the flying sunglass and that this transmission be no greater than 15% and preferably less.

2. It is recommended that sunglasses designated for general purpose should be as close to neutral as possible in order to preserve color discrimination and contrast perception at maximum for all colors.

3. In view of the fact that filters for special observa- purposes such as haze penetration, air-sea search, horizon viewing or air-snow search, must be designed and tested for the specific conditions of their use, the Services are invited to submit problems of this type to the Committee for study and investigation.

The following discussions presented to the subcommittee appear in the Proceedings:

A. The AAF Flying Sunglass. Major Pinson — 43

B. A Critical Comparison of Various Tinted Lenses for Aviation Sunglasses. Lt. Comdr. Peckham — 45

C. The Effect of Colored Goggles Upon Color Discrimination. Lt. Dean Farnsworth — 51

D. Visual Acuity and Contrast Discrimination Upon Color Discrimination. Lt. (jg) Verplanck — 71**

9. Major Rostenberg discussed the Army Ground Forces night vision testing and training program. — 56

10. Lt. Sulzman presented a report on the effect of interpupillary distance on performance on the Ortho-Rater. — 62

11. Lt. Farnsworth reported a study comparing binocular and monocular viewing of tests for monocular acuity on the Ortho-Rater. — 67

ABSTRACTS — 75**

**Confidential supplement

ARMY - NAVY - OSRD VISION COMMITTEE

PROCEEDINGS

Twelfth Meeting
National Academy of Sciences
Washington, D.C.
1000, 12 June 1945

3. REPORT OF THE SUBCOMMITTEE ON PROCEDURES AND STANDARDS FOR VISUAL EXAMINATIONS

As a result of the discussion of visual selection standards at the eleventh meeting of the Vision Committee, a Subcommittee on Procedures and Standards for Visual Examinations was appointed by the Chairman to explore the possibility of formulating recommendations for modification of present procedures and/or further research. The first meeting of the subcommittee was held 8 May 1945. The following were present:

Members of the subcommittee:
- Col. Derrick T. Vail, Chairman
- Capt. J. H. Korb
- Lt. Comdr. R. H. Peckham
- Major P. R. McDonald
- Lt. Dean Farnsworth
- Dr. Harry Gradle
- Dr. Donald G. Marquis, Secretary
- (Absent members: Dr. M. S. Viteles, Dr. Walter Miles, Dr. Alan Woods)

Others:
- Capt. C. W. Shilling
- Capt. C. R. Ball
- Dr. C. W. Bray
- Lt. S. H. Britt
- Ens. Kenneth E. Clark
- Major Daniel Deyoe
- Dr. Selig Hecht
- Wing Comdr. P. A. Lee
- Wing Comdr. S. R. C. Nelson

Questions raised by Lt. Farnsworth at the eleventh meeting of the Committee (Proceedings, 10 April 1945, pp. 57-60) and others posed by members of the subcommittee formed the basis for subcommittee discussion.

Several activities are working on the development of a valid acuity test object. The AAF School of Aviation Medicine and the Medical Research Department, Submarine Base, New London, have been working independently on the development of Snellen letters of approximately equal difficulty. The American Medical Association sponsors a letter chart. The Bureau of Medicine and Surgery is cooperating with the Bausch and Lomb and American Optical companies in the development of test targets whose purpose is directed towards measuring resolving power rather than the ability to read letters.

The subcommittee agreed that the work of the various activities should be brought together and the most reliable test object determined in order that a single test object for uniform use throughout the services can be recommended. The subcommittee, therefore, recommended that a representative from the AAF School of Aviation Medicine and a representative from the Medical Research Department, Submarine Base, New London, pool the results of their research on Snellen letters and develop a series of charts to be evaluated under controlled conditions against charts measuring resolving power (checkerboard and triangle targets) developed by Research Division, Bureau of Medicine and Surgery.

Problems of standardization of illumination, administration, and test-retest procedure for visual acuity testing were discussed. The subcommittee agreed that a training manual for testing visual acuity in the services should be written, incorporating subcommittee recommendations on these and related problems. Col. Vail and Lt. Farnsworth were appointed to formulate such a manual to be submitted to the Vision Committee for consideration.

The use of mechanical visual screening tests was discussed. There is a need for good (valid) clinical tests before the scientific value of visual screening tests can be determined. In the present state of development of visual screening tests, no recommendation can be made for their use as clinical working tests. Visual screening tests have been found valid, however, for selection of personnel for certain specialized military duties. The subcommittee agreed that further experimental work on visual screening devices is justified on the basis of present knowledge and should be encouraged.

Current validational studies in the Air Surgeon's Office, CominCh and Naval Air Station, Pensacola, were discussed briefly. The subcommittee favored studies checking the validity of predictions based on tests administered prior to training. No recommendation was adopted.

In any given exposure the target, brighter than the background, was presented in one of eight possible positions with respect to the central reference point. The observer was allowed to search about the reference point and was asked to give the target position relative to this point. Four of the eight positions were marked at the edge of the central field for easy reference. For each target size and shape the number of correct answers out of eight exposures was studied as a function of the brightness contrast. That contrast for which the observer obtained 5 correct answers out of eight exposures was taken as a measure of the just perceptable contrast.

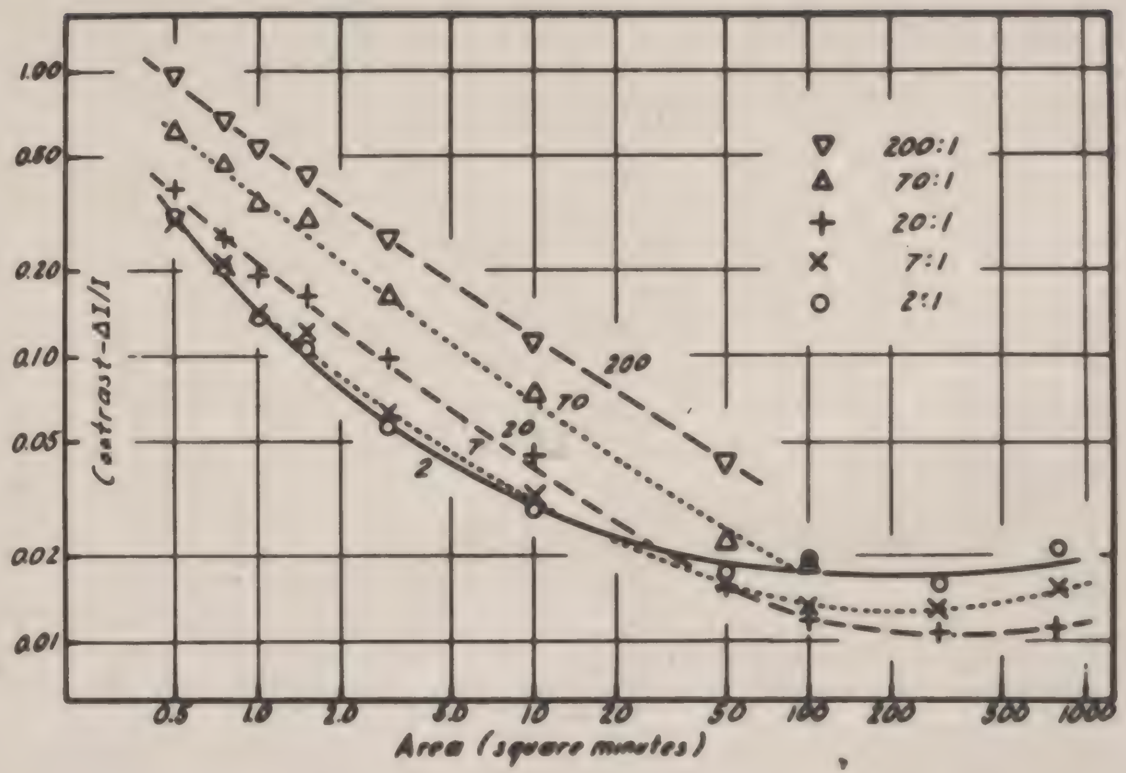
The targets were all rectangular in shape. They varied in size from 0.5 to 800 square minutes and in asymmetry factor, i. e., the ratio of length to width, from 2 to 200. Two background brightnesses were studied, one of 3000 foot lamberts corresponding to bright daylight illumination of terrain or ocean surface, and another of 20 foot lamberts corresponding approximately to twilight illumination. Measurements were made in 3 retinal regions, foveal, 1.25° parafoveal, and 10° out in the periphery. Although the constants involved differed for the various conditions of illumination and retinal region studied, all the data show the same general trends. As an example, the high brightness foveal data will now be presented.

Fig. 2 shows the high brightness foveal data. The ordinate is the just perceptible brightness contrast and the abscissa is the angular area. The different curves are for the different asymmetry factors. There is little difference between the data for asymmetry factors 2 and 7 showing that the earlier conclusions are supported for the small asymmetries. As the asymmetry factor is increased the effect of target shape becomes more important at least over part of the target area range considered.

As regards the correlation af all the data, you will notice first that, for asymmetry factors 2 and 7, the data follow a 45° degree line at small areas. This means that for these areas the product of contrast and area is constant, or, in other words, that in order for the target to be seen, the total flux must exceed a rather definite value. Furthermore, a closer examination of the data shows that for asymmetry factors 2 and 7, the departure from the 45° line begins in each case at about the same target length. The other asymmetries do not actually reach the 45° line but approach it and presumably would reach it at smaller values of area.

The constancy of the total flux along the 45° line and the fact that departures from the 45° line take place at about the same length suggests that it would be instructive to plot the total flux,

Fig 1



1.00
0.50
0.20
0.10
0.05
0.02
0.01
Contrast-ΔI/I
0.5
1.0
2.0
5.0
10
20
50
100
200
500
1000
Area (square minutes)
200:1
70:1
20:1
7:1
2:1
200
70
20
7
2

Fig. 2

i. e., the product of contrast and area, as a function of target length. This has been done and the result is shown in Fig. 3. Here it will be noticed that the total flux is indeed constant so long as the target length does not exceed about 3 minutes of arc. Beyond this point the flux required to perceive the target gradually increases.

In this figure another effect becomes apparent. The data for the various asymmetry factors break away, one after the other, from the lowest line shown. A careful examination here shows that the break-away in each case occurs at about the same value of target width, about 2 minutes of arc. The break-away in this case is sufficiently sharp to suggest that the flux gained by increasing the width beyond 2 minutes is entirely wasted so far as aiding in the perception of the target is concerned. In Fig. 4, therefore, we have considered only that flux which is not wasted, the total flux for targets less than 2 minutes wide, and the flux in a 1 minute strip inside the perimeter for the other targets. The flux so defined is presented in Fig. 5 as a function of the perimeter of the target. As can be seen from the figure, all the data follow the same curve so that our correlation is complete.

In order to describe the results just presented in terms of the known structure of the eye, we must fix our attention not on the target but on the image of the target which is formed on the retina by the optical system of the eye. Consider first a target so small that it is essentially a point. Because of the phenomena of diffraction, chromatic, spherical, and other aberrations in the optical system of the eye, this point target produces on the retina not a point image but rather a fuzzy disc several minutes in diameter.

Now let us suppose that this point target is drawn out into a line keeping the total flux the same. As the length increases, nothing much happens to the retinal image until the length of the target is of the same order of magnitude as the diameter of the disc image of a point source. Beyond this length of target, the retinal image becomes longer and less bright and can no longer be seen. In order for the target to be seen, the total flux must be increased as was shown in Fig. 3. This increase in flux is not enough to bring the image back to its original brightness. From this it can be concluded that the longer the target, the less bright it need be in order to be seen.

Now let us suppose that the long line target just considered is increased in width, keeping the length and total flux the same. As the width of the target is increased, again nothing much happens to the retinal image until this width is of the same order of magnitude as that of the retinal image of the line target. Beyond this width, the retinal image becomes wider and less bright and can no longer be seen.

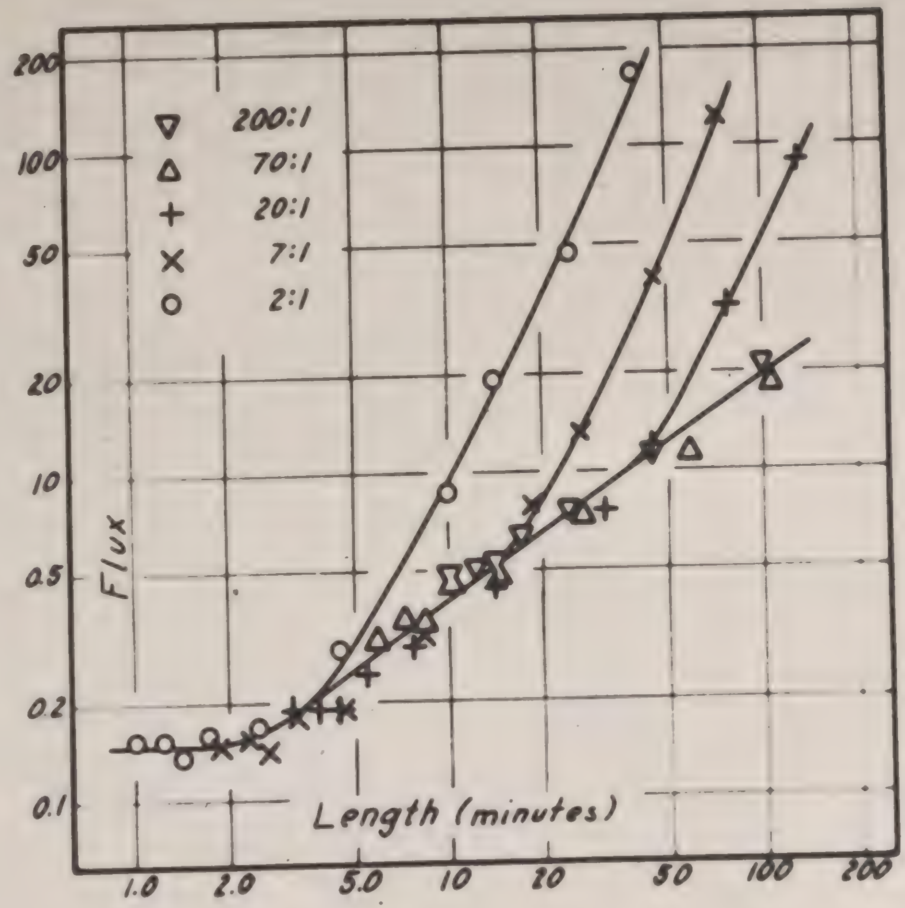
In order for the target to be seen the total flux must be increased enough to bring the brightness of the image back to its original value. In other words the image of a wide target must be just as bright as that of a narrow one in order to be seen so that beyond a definite width of target, further target width is completely wasted in making a visual judgment. This indicates that it is the edge and not the center of the target which contributes to the visual judgment. The longer this edge, the less the brightness difference required for the visual judgment.

Going back now to Fig. 2 let us see what this effect of target shape amounts to in terms of maximum sighting range for some target such as a submarine wake. The area of this target is about 13,000 square feet so that, if sighted at 7.2 miles from an altitude of about 2000 feet, it subtends a solid angle of about 4.5 square minutes. If seen end-on, the target appears to be reasonably symmetrical in shape so that it corresponds to the asymmetry factor 2 curve at about the point where it begins to depart from the 45° line. If this target is now seen from abeam so that its asymmetry factor is about 100, its angular size must be increased by a factor of 10 in order for it to be seen, if the contrast remains the same, i. e. if the visibility is unlimited. To accomplish this, the range must decrease by $\sqrt[3]{10}$ or from 7.2 to 3.3 nautical miles or by about 54%. As can be seen from Fig. 2, the effect of target shape is smaller for targets subtending less than about 4.5 square minutes, and smaller for targets subtending more than about 4.5 square minutes. Hence, the greatest effect on submarine ranges to be expected from target shape is about 54%. Under operational conditions, the visibility is seldom unlimited, so that the contrast itself varies with range. This tends to reduce any effect of shape on maximum sighting range.

Discussion:

Dr. Hardy suggested the possibility of developing a formula for use in determining visual acuity under specific conditions of target area and brightness based on the expression $\Delta F = \Delta B \times A$. If flux is concentrated at a point sufficiently small so that the most efficient use is made of it, visual acuity is plotted as a function of flux. If the target dimensions were expanded, efficiency factors, one depending on width and one depending on length, could be derived. Effective flux could then be expressed $\Delta F = \Delta B \times A \times E_h \times E_v$.

Dr. Lamar pointed out that the perimeter rather than the area of the retinal image is important. As soon as the expression is in the form of area x two efficiencies, it holds for only one target shape. Different efficiencies would be necessary for different target shapes.



200:1
70:1
20:1
7:1
2:1
Flux
200
100
50
20
10
0.5
0.2
0.1
1.0
2.0
5.0
10
20
50
100
200
Length (minutes)

Fig 3

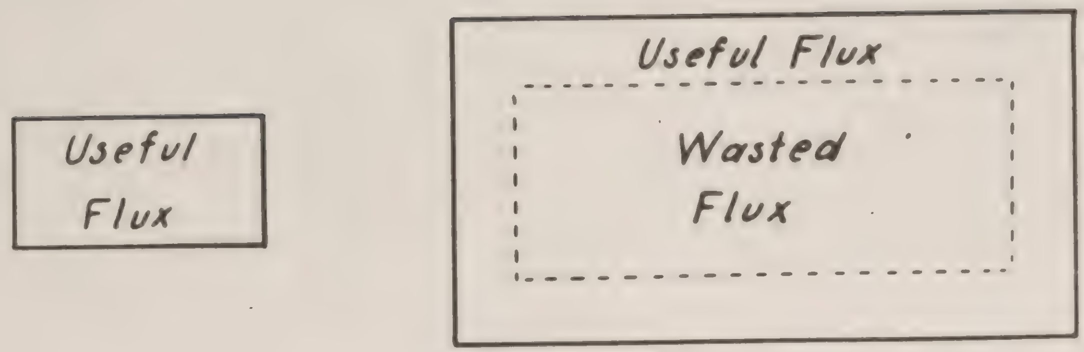


Fig 4

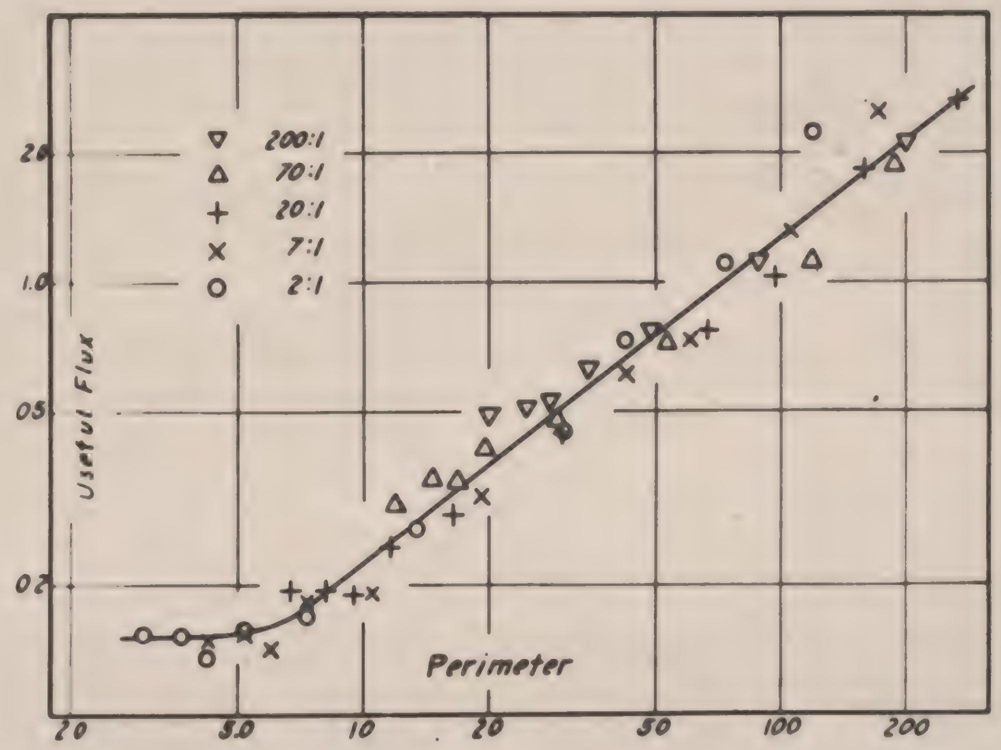

200:1
70:1
20:1
7:1
2:1
Useful Flux
Perimeter
2.0
1.0
0.5
0.2
20
5.0
10
20
50
100
200

Fig. 5

Dr. Hartline stated that a third efficiency factor - that of the perimeter - would make the expression workable.

In view of Dr. Lamar's statement that the effective flux in a visible target can be assumed to be contained in a perimetric area of $2-3^\circ$ width, the question was asked whether a signal such as a cloth or dye marker of specified area could be made more visible by distributing the area in the shape of a doughnut. No definitive answer was available and Dr. Hecht stated that such tests were included in the plans for further work.

7. REPORT NO. 1 OF THE SUBCOMMITTEE ON DESIGN AND USE OF BINOCULARS

The following report of the subcommittee was prepared by Dr. Selig Hecht acting for Dr. C. W. Bray, Chairman.

I. Membership and Mandate

1. The members of the subcommittee are:

Dr. C. W. Bray, Chairman
Comdr. S. S. Ballard
Lt. Col. R. S. Cranmer
Dr. Selig Hecht
Dr. Theodore Dunham, Jr.
Lt. C. G. Hamaker
Lt. Nathan H. Pulling
Lt. Harry London
Lt. (jg) W. S. Verplanck
Dr. Donald G. Marquis, Secretary

2. The subcommittee was appointed to (1) evaluate and interpret existing information about binoculars, (2) determine the need for further measurements, and (3) arrange, when feasible, for securing them.

3. The work of the subcommittee was facilitated by the request of the A-N-OSRD Vision Committee for a statement from Comdr. Ballard clarifying the needs of the Services. The statement by Comdr. Ballard, which is in the form of ten questions, served as the basis for the discussions and actions of the subcommittee, and is here quoted in full.

> Experiments with various types of binoculars and telescopes should be planned so as to provide answers to the following questions:
>
> 1. Which of the following binoculars are best suited for hand-held use in detecting and recognizing surface and aircraft targets at night?
>
> (a) Standard 7x50x7.1° binocular
> (b) Wide-field 7x50x10° BuAer Binocular Mark 41
> (c) 9x63x5° BuOrd Binocular Mark 37
> (d) 10x50x7° BuOrd Binocular Mark 36

2. What are the relative advantages of the above instruments and the following for mounted rather than hand-held use (mounted on gun directors, torpedo directors, gun mounts, target bearing transmitters, target designation equipments, etc.)?

(a) 6x50x7° BuOrd Telescope Mark 91 (binocular)
(b) 6x33x8° BuOrd Telescope Mark 60 (monocular)
(c) 10x70x7° Binocular
(d) 12x60x3.3° German Binocular

The 20x120x3° Ships Binocular Mark 1 should be included for comparison.

3. How much advantage is gained by a binocular over a monocular telescope for use at night?

4. What diopter setting should be used in fixed-focus instruments which are to be used both in the daytime and at night?

5. What advantage is gained in a mounted binocular telescope by an exit pupil larger than 7 mm.?

6. Should the eyepieces of binoculars and telescopes be set at night one diopter more negative than daytime settings? What loss in range of detectability obtains at night when incorrect diopter settings are used?

7. How critical is precise interpupillary adjustment of binocular viewing instruments at night?

8. What advantages are to be gained by using special headrests to shut out extraneous light and to position the eyes correctly?

9. What loss in range of detectability at night is produced by the use of a dimly-lit red crossline?

10. What are the contrast sensitivities and resolving powers of the dark adapted eye across the field of vision?

Results for both stationary and rolling platforms are desired; for the latter a 5° roll with a 12-second period is suggested. It should be borne in mind that naval instruments must effect a compromise among the optimum characteristics for various levels of external illumination, visibility, and target contrast.

Although primary emphasis should be placed on field investigations of these problems, I realize that some phases of

many of them can be more easily and perhaps more profitably studied with laboratory set-ups.

Although each of the above problems is of practical "everyday" importance, they have been arranged in order of their approximate priority; academic items of borderline applicability have been purposely omitted. Our present feeling is that the desire to obtain precise and complete data on each of these problems should be subordinated to the practical necessity of obtaining partially complete and approximate information which can be put to immediate use.

Although we are desirous of assisting in every way possible, I feel that the responsibility for organizing and carrying out the proposed investigations should be assigned elsewhere. Furthermore, I am of the opinion that the problems of this study are of such paramount importance as to merit the establishment of a standing subcommittee with a nucleus of temporarily full-time personnel.

Lt. Col. Cranmer states that the questions are of interest to Army Ordnance in approximately the same order, except that question 2 is not an Army problem. Question 1 should be modified to include low contrast terrestrial targets by day or night. Instrument (a) (7x50) is of principal interest, but two new observing devices T131 (15x) and T132 (20x) will be available for testing in a few months.

II. Meetings

The full subcommittee met on 8 May 1945*. It explored the problems, formulated some answers tentatively, and delegated work on several others to smaller groups. Of these subgroups, one met at the Submarine Base, New London, (Dunham, Hecht, Marquis, Pulling, and Verplanck) to consider questions 1 and 2; another (Pulling and Verplanck) arranged the details of the experiments contemplated in answer to questions 1 and 2; and a third (Hartline) at Philadelphia worked over questions 5, 7, and 8. All groups reported to a full subcommittee meeting on 11 June 1945**, following which a smaller

*Non-members attending: Capt. C. W. Shilling, Mr. John Darr, Miss Lillian Elveback, Lt. Dean Farnsworth, Lt. Comdr. R. H. Peckham, Dr. Richard Tousey, and Dr. F. E. Wright.

**Non-members attending: Capt. C. W. Shilling, Lt. Ellsworth B. Cook, Mr. John Darr, Miss Lillian Elveback, Dr. E. O. Hulburt, Dr. Walter Miles, Lt. Comdr. R. H. Peckham, Ens. Sherman Ross, and Dr. F. E. Wright.

group (Hartline, Hecht, Pulling, and Verplanck) drew up formal answers to the questions.

III. Proposed Tests of Instruments for Night Use.

1. Questions 1 and 2 could be answered in good part from available laboratory studies. However, from the service point of view, it was clear that a certain amount of field experimentation is required to validate and supplement the laboratory evaluation of the relative importance of magnification, field size, exit pupil, and binocular vision in the various instruments. It was therefore decided to undertake a large scale field experiment in which only experienced observers from the various Services and Research Laboratories would take part, and which would be designed for precisely this purpose.

At the invitation of Captain Shilling a few members of the Subcommittee made a preliminary survey of the region of the Submarine Base at New London, and themselves undertook some tests for 2 nights, in order to see whether a large scale experiment could be set up. The report of this group is entirely favorable. Even the two evenings work, by 6 and 4 observers respectively, showed that field evaluations were possible, and that if amplified and extended are sure to supply reasonably adequate evaluations of the relative importance of the several variables involved in the night binocular and telescope problems.

2. The arrangements for the field tests are still tentative, but the major points are clear. The first 2 1/2 weeks of August and of September will be practically moonless, and will give ample time for the measurements. Observations will be made from the deck of a Destroyer Escort vessel which will cruise in a specified area in Long Island Sound. Moving targets such as minesweepers, submarines, and airplanes, and stationary targets such as colored lights, floating buoys, and specially prepared test squares will be available. Ranges will be recorded by radar. Both hand-held and mounted instruments will be tested. It is planned to compare only 6 instruments in each case, and to use six observers every evening.

The details of the arrangments are given in "Outline of Proposed Tests of Optical Instruments for Night Use," which follows this report (7A, pp. 27-29).

3. The observers for this field experiment are to be the members of the Army-Navy-OSRD Vision Committee, and of interested research organizations.

We wish to take this opportunity to invite the members of the Vision Committee to participate in the program and to make it one of their important items of business. In the near future formal invitations will be issued in terms of which orders can be written. We hope that each member, and anyone else whom he considers appropriate, will cooperate in this experiment. It is expected that at least 2 nights, preferably 3, and if possible 4 for each member will be devoted to the project. Schedules will be arranged as soon as answers have come from the invitations.

4. At first the Subcommittee had hoped to make up a series of kits each containing 5 or 6 of the binoculars in question and to loan such kits to various laboratories for field trials and evaluation. However, because of the difficulty of securing some of the most recent instruments of which only one or two trial models have been made, this idea has not proved practical. As soon as it becomes practicable, kits will be made up and distributed.

IV. Answers to Questions.

Of the remaining questions some were answered tentatively at the first meeting of the Subcommittee, while some were referred for study to several members, particularly Dr. Hartline. The formulation of these answers in short paragraph form is here given. The sources of the data, and the computations underlying the answers are included in a following report (7B, pp. 30-39).

Question 3. How much advantage is gained by a binocular over a monocular telescope for use at night?

Answer: When a visual task such as contrast discrimination or form recognition is difficult and marginal, the use of a binocular instrument is of advantage over a moncular. The extent of the advantage varies with the uncertainty of decision involved in the task. Expressed in terms of the frequency of seeing the target, the binocular advantage increases from zero to 100 percent as the uncertainty of the task increases.

Translated into range this means that for the same frequency of seeing a target the expected gain in range at night varies between 10 and 25 per cent, depending on the brightness. It is the impression of a number of observers that this gain in range represents an underestimate, particularly as concerns the confidence with which a target is seen binocularly compared to monocularly.

Question 4. What diopter setting should be used in fixed-focus instruments which are to be used both in daytime and at night?

Answer: Further research concerning optimum setting for fixed-focus instruments which are to be used both in the daytime and at night is actively under way (Dr. George Wald for the NRC-CAM Subcommittee on Visual Problems.) If a recommendation is immediately necessary, the Subcommittee accepts the British recommendation of -0.75 to -1.0 diopter.

Question 5. What advantage is gained in a mounted binocular telescope by an exit pupil larger than 7mm.?

Answer: There are two obvious advantages in using an exit pupil larger than 7mm. on a mounted binocular telescope: (a) increase in retinal illumination and (b) maintenance of constant retinal illumination during roll, pitch, and vibration. (a) The increase in retinal illumination occurs only in that fraction of the population whose pupil diameter is greater than 7mm; for these the increase will vary from 0 to 30 per cent corresponding to an increase in range from 0 to 10 per cent with an average of 5 per cent for the whole population. (b) The advantage for roll, pitch, and vibration cannot now be estimated but will be investigated at Brown University.

Question 6. Should the eyepieces of binoculars and telescopes be set at night one diopter more negative than daytime settings? What loss in range of detectability obtains at night when incorrect diopter settings are used?

Answer: There is good reason to accept the British finding that the eyepieces of binoculars and telescopes used at night should be set one diopter more negative than daylight settings. According to these reports, settings as little as one diopter different from this negative setting may produce a loss as great as 10 per cent in the range at which a target may be detected. Greater deviations, it may be assumed, will lead to disproportionately greater losses in range as well as to visual discomfort and possible eyestrain.

More research clearly needs to be done here and has been started by a project under CMR-CAM.

Question 7. How critical is precise interpupillary adjustment of binocular viewing instruments at night?

Answer: Incorrect settings of the interpupillary distance decrease the advantage of a binocular over a monocular instrument. The maximum loss is suffered by those individuals whose pupil is precisely the same size as the exit pupil of the instrument, in which case the loss per millimeter error is about 1/4 of the bino-

cular advantage. For the population as a whole using an instrument with a 7 mm. exit pupil the loss on the average is about 0.1 of the binocular advantage for 1 mm. error, and 0.4 for a 2 mm. error.

For a 5 mm. exit pupil greater errors in interpupillary distance can be tolerated without loss of binocular advantage. In addition to the light losses, disadvantages are to be expected because of retinal rivalry.

Question 8. What advantages are to be gained by using special head-rests to shut out extraneous light and to position the eyes correctly?

Answer: Considerable advantage is to be expected from the use of head-rests or eye guards for shutting out extraneous light and wind, and for positioning and steadying the binoculars. The precise structure of such head-rests or eye guards is important because poor ones are worse than none at all.

It is recommended that special attention be devoted to the design and development of such head-rests or eye guards.

Question 9. What loss in range of detectability at night is produced by the use of a dimly-lit red crossline?

Answer: The Committee is unwilling to answer this question because the conditions as stated are not sufficiently specific. It would gladly consider a reformulation of this question with more definite description of the problem.

Question 10. What are the contrast sensitivities and resolving powers of the dark adapted eye across the field of vision?

Answer: This question involves so many variables that the Committee prefers not to answer it in its present form. The Committee would appreciate knowledge of the precise problems for which the question was formulated.

A. OUTLINE OF PROPOSED TEST OF OPTICAL INSTRUMENTS FOR NIGHT USE

1. The purpose of the test is to validate and supplement laboratory evaluation of the relative importance of magnification, exit pupil, field size, and binocular vision in the design of hand-held and mounted telescopes for use at night. They will also enable interested representatives of the Army, cognizant materiel Bureaus, Naval training commands, and research laboratories to witness the tests and to try out the various instruments under service conditions. Not only will qualitative evaluations be possible, but the tests will be arranged so that sufficient data on range of detectability and recognition can be acquired to enable the results to be expressed in quantitative form.

2. The observers will be selected from the Army-Navy-OSRD Vision Committee and interested research establishments, and it is expected that Prospective Commanding Officers of Submarines and experienced Naval lookouts will also be used.

3. The following instruments will be tested:

Hand-held:
- (a) Standard 7x50x7.1° binocular
- (b) Wide-field 7x50x10° Binocular Mark 41
- (c) 10x50x7° Binocular Mark 36
- (d) undetermined
- (e) undetermined
- (f) undetermined

Mounted:
- (a) Standard 7x50x7.1° binocular
- (b) 10x70x7° binocular
- (c) 6x33x8° Telescope Mark 60
- (d) 4x28x10° Telescope Mark 79
- (e) 20x120x3° Ships Binocular Mark 1
- (f) undetermined

4. Observations will be made during August and September 1945 on nights when the phase of the moon is suitable. These periods will be 2-18 August and 1-20 September.

5. On each run the targets will be:

   (a) Several small colored signal lights and a series of 10'x10' black targets located on a ruined fortification in Gardiner's Bay.

(b) A minesweeper or vessel of similar size, a camouflaged submarine, an uncamouflaged submarine, and several small craft.

(c) Floating buoys which simulate mines.

(d) Airborne targets, if practicable.

Each of the targets will be arranged so that with regard to it the following data can be determined for each observer on each run: (1) the range of detection; (2) the range at which it is recognized; and, for several of them, (3) the range at which changeable details can be distinguished. With this data an analysis can be made which gives the comparative usefulness of each type of instrument for locating several different types of targets and for identifying them.

6. The observation vessel will be a Destroyer Escort which will cruise back and forth over a course of approximately 5000 yards, at one end of which the targets listed under (a) will be placed, and at the other end, the targets listed under (b) and (c). On any one night approximately eight round trips can be made. Six observers will be posted forward of the steering station on the navigating bridge level to observe through two round trips at a time; six other observers will alternate with them. A full complement of six observers per run will be maintained by filling the ranks with experienced observers from the New Construction Training School, ComSubsLant.

7. Communication will be established between the observing vessel and the target. A radar plot for each run, including time notations, will enable the ranges of detectability and recognition for each target to be determined from time data made at the observing stations. Sound-powered telephones will permit communication between the observing station and central control station on the observing ship.

8. Visiting observers will come for a minimum of two nights of observations, so that every observer can use each instrument for at least one round trip. All visitors are encouraged to stay for three or four nights, if possible, since then the results of their observations will be more reliable. A questionnaire setting forth personal preferences, suggestions, and miscellaneous qualitative observations will be filled out by each observer.

9. Weather predictions will be available, and if inclement weather is forthcoming visitors who have not arrived will be advised by dispatch. Quarters and train reservations for visiting observers will be provided.

10. In order to carry out this program the following personnel will be necessary.

4 officers:	OinC of tests, stationed at central control. One officer at observing station. One officer ashore to make arrangements during the daytime. One relief.
18 enlisted men:	Telephone talker to bridge, stationed in central control station. TBS and Walkie-talkie operator, stationed in central control station. Plotter, in central control station. Four men to man targets on fortification. Six recorders, one for each observer. Two supernumeraries aboard ship. Three reliefs on shore. An unspecified number of experienced lookouts from new construction vessels to fill the complement of twelve observers for each observing night.

Both officers and enlisted men should be thoroughly familiar with a variety of jobs so that they can rotate duties and relieve each other.

B. CALCULATIONS INVOLVED IN ANSWERS TO QUESTIONS 5, 7, AND 8

The following papers have been prepared by Dr. H. K. Hartline, Johnson Research Foundation, University of Pennsylvania, under Contract OEMsr-1228, Section 16.1, NDRC.

I. Effect of the Size and Variability of the Pupil of the Eye on the Choice of Exit Pupil Size for Night Binoculars

The design of binocular telescopes for use at night is influenced by a consideration of the size of the pupil of the human eye, and its variation under different conditions and among different observers. Within limits, the larger the exit pupil of the telescope the more light will be admitted to the observer's eye and the better he will see; moreover, alignment of the instrument will be less critical when it is hand-held or used on a vibrating or moving platform. Large exit pupils, however, can only be obtained at the expense of other desirable features; either the magnification must be reduced or the size of the objectives, and hence the bulk and weight of the entire instrument, must be increased. It is, therefore, desirable to make a quantitative estimate of the advantage of a large exit pupil in a night binocular.

There have been several studies made of pupil size, published in the older literature. The most useful for the present purpose, however, is a recent short survey by British workers (ARL/N.2/O.502). From infrared photographs the pupil sizes of 52 service men were measured under adaptation to a series of illuminations covering those met at night. Similar measurements by Wagman on several of the Brown observers are in excellent agreement with these British data. Wagman has analyzed the British data, and finds that the pupil areas are normally distributed with a standard deviation $\sigma = 9.3$ mm.^{2} The average pupil area varies from 43.9 mm.^{2} (7.47 mm. diameter) in total darkness to 36.2mm.^{2} (6.79 mm. diamter) at 10 µL (moonlight) (σ remains unchanged over this range). Table I gives the values for intermediate adaptation values.

From this information it is possible to compute the fraction of the population whose natural pupils exceed a specified value, at a given brightness level. These individuals would profit to the full amount by any increase in exit pupil up to the specified value. Examples are given in Table II, for five adaptation levels.

TABLE I

Average area of the pupil at different levels of adaptation in a group of service personnel (British data). Column (1) gives the brightness level to which the observers were adapted, (2) gives the mean pupil area interpolated from the British curve, (3) the standard deviation of the distribution of areas (interpolated). The distributions are closely fitted by a normal curve at all levels studied.

(1) B µ lamberts	(2) A mean mm.^{2}	(3) σ mm.^{2}
0	43.86	9.33
.01	42.66	9.17
.1	40.58	9.29
1.	38.85	9.24
10.	36.18	9.40

TABLE II

Percentage of the population whose pupils exceed a specified diameter, at various levels of adaptation brightness (calculations based on British data).

Exit pupil diameter	Percent of observers whose natural pupils exceed exit pupil diameter				
	B = 0	B = .01 µL	B = .1 µL	B = 1.0 µL	B = 10 µL
5	100	99	99	98	96
6	95	94	90	87	80
7	72	67	58	52	40
8	25	21	14	11	7
9	2	1	1	0	0

Thus one-quarter of the population can utilize fully an eight millimeter exit pupil under very dark conditions.

From these data we can estimate the average, over-all gain in brightness for the population as a whole that may be expected from increasing the exit pupil from one value to another. Thus increasing a 7 mm. exit pupil to 8 mm. will increase the brightness of the telescope image by the ratio 64/49 — an increase of 30%. The full amount of this increase will be obtained by 25% of the population, under very dark conditions, since this fraction have natural pupils as large as or larger than 8 mm. However, an additional 50% of the population will obtain some improvement in brightness from the larger exit pupil, for this fraction have pupils between 7 mm. and 8 mm. For these observers the gain will vary from 0 to the full amount, and since the mean of the group lies midway between 7 and 8 mm., the average gain will be $\frac{1}{2}$ of the full amount, i. e., 15% in brightness. The remaining 25% of the population, having pupils less than 7 mm. will derive no benefit from the increased exit pupil, as far as the perfectly steady, perfectly aligned instrument is concerned. From these considerations it is obvious that the average, over-all gain in brightness for the entire population will be 15%, i. e., $\frac{1}{2}$ of the full amount expected from the relative exit pupil areas.

While this overall figure is valuable, it may not necessarily be the most significant measure of the gain to be expected in increasing the exit pupil. Thus it might be more significant that 25% of the population achieve the full gain in brightness (30%) and that an additional 50% of observers profit to some smaller extent as well. The improved performance of these fortunate observers may be more important than is expressed by the figure of 15% average increase in brightness.

To obtain values for average over-all gain for other exit pupil sizes and under different illuminations is not as easy as in the case given above, where the exit pupil sizes in question were symmetrically placed with respect to the mean pupil size of the population. It may be done by averaging the retinal illumination - external brightness multiplied by pupil area - for the population when using an exit pupil of given size, and comparing this average with that obtained when no limiting stop is placed in front of the eyes (maximum obtainable). Since the normal frequency distribution curve describes the data on pupil size quite accurately, this averaging may be done analytically, by integration and reference to the tables of the probability function and probability integral. The results of this computation, for several sizes of exit pupil at different levels of adaptation brightness, are given in Table III.

TABLE III

Average, over-all effect of exit pupil on relative image brightness (I), and range of detection (r) for the entire population, at various levels of adaptation brightness. Column (1) gives the adaptation level (B), and in parentheses the value of $m = \dfrac{d \log r}{d \log B}$. Column (2) gives the values of exit pupil diameter (D), column (3) the corresponding ratio of relative image brightness I_D averaged for the population to I_M, the relative image brightness at that adaptation level when no limiting exit pupil is used. Column (4) gives the percent gain or loss of image brightness, referred to the value for 7 mm. = 100%. In column (5) these values have been converted into gain in range, again referred to the values for 7 mm. = 100%.

(1)	(2)	(3)	(4)	(5)
B	D	$\dfrac{I_D}{I_M} \times 100$	$\left(\dfrac{I_D}{I_7} - 1\right) \times 100$	$\left(\dfrac{r_D}{r_7} - 1\right) \times 100$
uL	mm.	%	%	%
0	5	45	-47	-27
	6	64	-24	-13
(m = .50)	7	84	0	0
	8	97	+15	+ 7.5
	9	100	+19	+ 9.0
.01	5	46	-46	-24
	6	66	-23	-11
(m = .45)	7	86	0	0
	8	98	+14	+ 6.0
	9	100	+16	+ 7.0
.1	5	49	-45	-16
	6	69	-22	- 7
(m = .28)	7	88	0	0
	8	98	+11	+ 3.0
	9	100	+13	+ 3.5
1.	5	50	-44	-15
	6	71	-21	- 6
(m = .28)	7	90	0	0
	8	99	+10	+ 2.5
	9	100	+11	+ 3.0
10	5	54	-42	-17
	6	75	-19	- 7
(m = .35)	7	92	0	0
	8	99	+ 7	+ 2.5
	9	100	+ 8	+ 3.0

From this table it is seen that the maximum obtainable retinal illumination is attained by the 9 mm. exit pupil – there are too few individuals with pupils exceeding 9 mm. to contribute appreciably to the over-all average. Moreover, the maximum is very nearly attained by an 8 mm. pupil. Comparing the 7 mm. pupil with the 8 mm. for total darkness shows 84% of maximum as compared with 97% – an increase of 15% when referred to the 7 mm. value, in accordance with the simpler calculation made above. This improvement is cut down to 11% at star-lit sky levels of brightness, and to 7% in full moonlight. Subject to the limitations considered above, these relative values of over-all average retinal illumination for various exit pupil sizes may be used in comparing various binocular telescopes used by the general population.

Effect on Range of Detection. The above computations describe the effect of exit pupil area on the brightness of the image viewed through the binocular telescopes. Upon this depends the various visual functions – detection, recognition, probability of seeing, etc. To convert these values into figures that may have more significance in practical problems, reference must be made to measurements of these visual functions at different levels of brightness of the scene that is viewed. Ample data exist relating the brightness of a background to the range of detection of an object contrasted against it. For the present purpose, it is necessary only to know the rate of change of detection range with background brightness, for a representative target under various levels of illumination. Preliminary data from the Tiffany Foundation have been used for this purpose; data from other sources are in agreement with them. From the graph relating log r to log B, for an object of unity contrast, the slopes

$$m = \frac{d \log r}{d \log B}$$

have been read off and are tabulated in column 1 of Table III.* Application of these slope factors to the gain or loss in image brightness gives the gain or loss in range of detection for that level of illumination (if the gain or loss is more than 10%, the factor must be applied to the logarithm of the brightness ratios rather than to the percentage gain or loss). The results are given in column (5) of Table III. This column may be thus used in comparing the effect of exit pupil size with other factors affecting the range of detection of targets at night by binocular telescopes.

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*It should be mentioned that the values of slope given here may be underestimates when applied to the use of binoculars at very low brightness levels (.01 µL or less). Both British data and data from Brown agree in showing an undue falling off of range with decreased background brightness at very low levels. This accentuates the importance of a large exit pupil on very dark nights.

II. Effect of Errors in Setting the Interpupillary Distance of Binocular Telescopes on Target Detection at Night

Failure to set the interpupillary distance (IPD) of a pair of binoculars to coincide exactly with the interpupillary separation of the observers' eyes causes vision to become poorer and decreases the value of the instrument. Part of the decrease is undoubtedly due to discomfort and eye strain, and the presence of annoying shadows in the field that come and go as the alignment of the instrument changes. It is difficult to assess these factors quantitatively, but it is possible to compute the effect on vision that will result from the simple loss of light from failure to use the full apertures of the instrument.

Error in IPD setting may either be divided equally between the two eyes, decreasing the brightness of the images in both, or one eye may be aligned correctly with its telescope and the full error taken by the other eye. It is clear that if the error is very great the latter is the only suitable way to use the instrument, which then becomes only a monocular telescope. At its worst, then, IPD error causes the loss of the advantage that a binocular instrument possesses over a monocular. Therefore, the first step in evaluating the effect of IPD error is to estimate this advantage quantitatively.

The author is not aware of direct experimental comparison of monocular vs. binocular instruments under the conditions pertinent to this problem (one side of a binocular instrument covered). There are, however, naked eye observations which have established the simple principle that at low levels of illumination the two eyes function independently in detecting targets, so that the probability of detecting a target with both eyes is better than that with one eye alone.*

For a given level of probability of seeing, the target will accordingly be detected at lower brightnesses or at greater ranges with two eyes than with one. The magnitude of the improvement may be calculated from the "frequency of seeing" curve relating probability of detection, p, to either brightness or range.

If one is to fail to see an object, it must be missed by both eyes at once. The probability of missing it with both eyes is therefore the product of the probability of missing it with each eye separately:

$$Q_{1+2} = q_1 \times q_2 \qquad \begin{array}{l} p = \text{probability of seeing} \\ q = \text{probability of missing} = 1-p \end{array}$$

*Pirenne, reported verbally by Dr. Hecht. This problem has been discussed at earlier Vision Committee meetings.

If the two eyes are equal and are equally illuminated, the "frequency of Seeing" curve for both eyes will be obtained from the frequency of seeing curve for a single eye by the above formula, with $q_1 = q_2$. This will give a curve displaced towards lower brightnesses (or toward larger ranges) by the maximum amount; if a given level of probability, say 50%, is chosen as "threshold seeing", this displacement will be the binocular gain. If the two eyes are not equally illuminated, q_1 and q_2 will not be equal, but will be given by frequency of seeing curves that are separated by an amount determined by the difference in illumination. The new curve plotted from Q_{1+2} will again be displaced towards lower brightnesses, but not as much as before; i.e., some of the binocular advantage will be lost.

In making these computations for the problem of IPD error we have started with an average frequency of seeing curve provided by the Brown experiments (courtesy of Dr. Miller and Mr. Beck). This curve gives the probabilities of detecting targets of various sizes correctly in one of six possible positions on a screen. It was obtained using binoculars at low levels of illumination and hence is especially pertinent to this problem. Except for the extremes of the curve, it is adequately described by an integral probability curve for which $\sigma = .064$ log units of visual angle (range). To translate this into terms of brightness, we have divided the log range values by .28, which is the mean slope $\frac{d \log r}{d \log B}$ of curves relating range to background brightness. This yields a value of $\sigma = .23$ log units of brightness. This Brown curve is for binocular vision; to obtain the basic curve for a single eye we applied the equation $q_1 = \sqrt{Q_{1+2}}$, in accordance with the discussion above. We were than able to obtain values of q_2 for the eye for which the brightness had been reduced as a result of loss of aperture from the IPD error, and thus compute how much of the binocular advantage had been lost as a result of the error. By plotting log q vs. log B this computation can easily be made graphically for a given level of probability (50% in these computations). The results are given in Table I. If this were the only factor operating, the binocular advantage would be only .16 log units of brightness (= 10% in range at starlight levels). This advantage, moreover, is lost almost completely if the brightness in one eye is reduced to 1/3 that in the other. (For higher levels of probability the advantage calculated on this basis is appreciably higher; e.g. at p = 90%, the advantage is .23 log units of brightness, 16% in range).

We may not evaluate the effect of IPD error by computing the light loss resulting from a given error, referring to a graph prepared from Table I to find the loss in effective brightness, and hence, in range. Table II gives the results of this computation for

TABLE I

Binocular advantage, calculated on the basis of probability of detection = 50% for two eyes illuminated differently (I_1 & I_2). Column (1) gives values of $\log \frac{I_1}{I_2}$. Column (2) gives the value of $\log \frac{I_1}{I_{1+2}}$, where I_{1+2} is the brightness at which both eyes together yield a probability of detection of 50%.

(1)	(2)
$\log \frac{I_1}{I_2}$	$\log \frac{I_1}{I_{1+2}}$
0.0	.16
0.1	.11
0.2	.07
0.3	.04
0.4	.02
0.5	.01

TABLE II

Losses in effective brightness and in range of detection for various amounts of error in IPD setting, for an observer whose pupil size equals the exit pupil size of the binoculars. Column (1) gives the IPD error; column (2) gives the loss in log brightness if the IPD error is equally divided between the two eyes; column (3) gives the effective loss in log brightness if one side of the instrument is correctly aligned with the eye, and the total IPD error taken by the other eye. Column (4) gives the values of column (3) expressed in % loss in brightness; column (5) the same results in % loss in range of detection assuming an average change in log range with log brightness of .28 (average night conditions).

(1)	(2)	(3)	(4)	(5)
IPD error mm.	Δ log B (error divided)	Δ log B (error all on one side)	$-\frac{\Delta B}{B} \times 100$ %	$-\frac{\Delta r}{r} \times 100$ %
0.5	-.02	-.02	4.5	1.3
1.0	-.04	-.04	9.1	2.6
2.0	-.09	-.08	18.	5.0
3.0	-.14	-.12	24.	7.7
4.0	-.19	-.145	28.	9.0
(monocular)	-	-.155	30.	9.5

an observer whose pupil is exactly equal to the exit pupil of the instrument and who has aligned the instrument correctly with one eye, taking the entire IPD error with the other. For comparison, the loss in brightness has also been computed for the case when the error is divided equally between the two eyes.

It is seen that for small errors it makes little difference how the instrument is used, but that for errors greater than 2 mm. it is appreciably better to use one side of the instrument in correct alignment. It is also seen that a 4 mm. error almost completely destroys the binocular advantage.

Table II also gives the % loss in effective brightness for various IPD errors, assuming correct alignment of one side of the instrument. Corresponding range losses are also given, on the basis of $\frac{d \log r}{d \log B} = .28$, for average night conditions. For very dark nights these range losses will be doubled.

The above computations are for an observer whose pupils are the same size as the exit pupils of the instrument. Because the pupil of the eye varies in size from person to person, and changes with different conditions of illumination, it will in general not match the size of the exit pupil, and many observers will be able to tolerate a small error in IPD setting without losing any aperture.

Aperture will begin to be lost only when the IPD error equals the difference in diameter between natural pupil and exit pupil. For the population in general, then, the only observers who will suffer from a given error in IPD are those whose pupil sizes fall within the limits of exit pupil diameter plus and minus IPD error. For them, the loss in aperture, hence in range, will vary from 0 to the full amount possible for the given IPD error. One may obtain an over-all average from the entire population by weighing properly the losses by the proportion of observers in the population suffering such losses.

Thus for an IPD error of 1 mm., with an instrument exit pupil = 7 mm. observers whose natural pupil on a moderately dark night are less than 6 mm. and greater than 8 mm. constitute 10% and 14% of the population respectively. (-1.29σ and $+1.08\sigma$ from the mean of 7.15 mm.; cf. previous paper on pupil size). Thus 24% will suffer no loss from a 1mm. IPD error. In the remaining 76% the loss will vary from 0 to 9% in brightness, and will average approximately half of this (since the distribution is fairly symmetrical on either side of 7mm.) For the entire population the over-all average loss may be expected to be $\frac{.76 \times \frac{1}{2} \times 9\%}{1.0} = 3.4\%$.

in brightness, 9% in range. More exact averaging may be performed analytically for this and other values of IPD errors; the results, for moderately dark conditions, are given in Table III. For very dark nights the range losses will be approximately doubled.

TABLE III

Average loss in brightness and range for the entire population, resulting from IPD error. Calculated for .1 µL level of adaptation, with an instrument having 7 mm. exit pupils. For darker conditions the brightness losses will be only slightly changed, the range losses approximately doubled. Column (1) gives the IPD error. Column (2) gives the effective % loss in brightness; column (3) the corresponding % loss in range of detection.

(1)	(2)	(3)
IPD error	Av. $-\frac{\Delta B}{B} \times 100$	Av. $-\frac{\Delta R}{R} \times 100$
mm.	%	%
.5	2.6	.7
1.0	4.0	1.1
1.5	8.3	2.3
2.0	13.8	3.7
2.5	18.5	4.9
3.0	24.0	6.2

Table III permits an estimate to be made of the losses resulting from instruments with fixed IPD. If several "sizes" are provided, no one observer need have an instrument differing by more than ½ "size" from his correct IPD setting; the population in general will have errors varying from 0 to the value of ½ the size interval, and will average (if the size steps are not too large) ¼ the size interval. These observers however, have pupils of various diameters, and Table III gives the average over-all loss for the mean IPD error. Thus a size interval of 4 mm. may be expected to give on the average losses corresponding to 1 mm. IPD error or 1% in range of detection. To cover the range of IPD variation most efficiently it would probably be advantageous to have the steps in size closer together in the middle of the range than at the extremes. Table III could be used to assist in finding the optimum step sizes.

These computations only consider the more tangible factors concerned in evaluating IPD errors; other factors of comfort and eye strain and general annoyance with a badly fitting instrument cannot be completely neglected.

8. REPORT OF THE SUBCOMMITTEE ON SUNGLASSES

In response to request from the Chief of the Aero Medical Laboratory, Air Technical Service Command, the Chairman appointed a Subcommittee on Sunglasses to consider the question of optimum color and density for the flying sunglass lenses as a basis for possible Army-Navy standardization. The first meeting of the subcommittee was held at the National Academy of Sciences at 1400, 11 June 1945. The following were present:

Members of the subcommittee:
- Dr. W. R. Miles, Chairman
- Lt. Arthur Braun
- Dr. W. W. Coblentz
- Lt. Dean Farnsworth
- Dr. H. K. Hartline
- Dr. Selig Hecht
- Lt. Comdr. R. H. Peckham
- Major E. A. Pinson
- Lt. N. H. Pulling
- Capt. Richard Toucey
- Dr. Donald G. Marquis, Secretary
- (Absent members: Dr. D. W. Bronk, Dr. Brian O'Brien)

Others:
- Dr. Franklyn Burger
- Comdr. Oran W. Chenault
- Lt. Ellsworth B. Cook
- Lt. Col. A. P. Gagge
- Dr. E. O. Hulburt
- Mr. Harry J. Keegan
- Capt. J. H. Korb
- Ens. Sherman Ross
- Capt. C. W. Shilling
- Lt. (jg) W. S. Verplanck

The following questions were formulated as the basis for subcommittee discussion:

1. Can the services adopt the same requirements for transmission in the flying sunglass?

2. Should the sunglass be neutral, rose-smoke, or some other tint, in view of

    a. possible loss in color perception
    b. possible loss in visual acuity
    c. possible gain in contrast perception under certain conditions of cloud, haze, etc.

3. Similar questions with respect to filters in telescopes and other viewing devices.

Major Pinson summarized the needs and requirements for sunglasses in the AAF (8A, pp. 43-44). The present AAF flying sunglass is issued to every crew member and is a rose-smoke of 15% transmission which is thought to give adequate protection for the range of brightnesses encountered under most job conditions. The

rose-smoke was a development based on Arctic experience. An experimental rose-smoke lens graded in the upper segment of the field from 15% at the center to 0.1% at the top is being developed for crew members whose positions demand greater protection (top- and side-gunners).

Capt. Korb stated that the Navy flying sunglass has a non-polarizing neutral lens of from 17 to 27% transmission. The Navy provides the brow-rest 10-12% transmission, polarizing, neutral glasses for glare protection to all personnel. He explained that the stated transmission for the flying sunglass was about as low a requirement as could be accepted since the glasses are worn from dawn until dusk. Wide variations in jobs make the Navy requirements for sunglasses difficult to define. On coral reefs or for use in air-sea search, greater density is required, but a somewhat higher transmission is comfortable in the air.

Lt. Comdr. Peckham pointed out that Navy flyers are divided into day and night flyers. The purpose of sunglasses for night flyers is to preserve potential dark adaptation. These flyers use the 10-12% neutral polarizing glasses. The purpose of sunglasses for day flyers is to provide comfort, a requirement that is satisfied by the general issue flying sunglass (17-27% transmission) without any loss of visual functions. Lt. Comdr. Peckham summarized the history of protective sunglasses, gave spectrographic data and methods of comparing various lenses, and discussed procurement problems (8B, pp. 45-50).

Lt. Farnsworth discussed results of several methods used to determine the effect of tinted lenses on color perception (8C, pp. 51-55). On the basis of these tests the amount of tolerance that can be permitted in a general purpose glass may be determined. Lt. Farnsworth suggested a limit of Chroma 3 on the Munsell scale. As a basis for judging the effect of the rose-smoke lens on color perception, Lt. Farnsworth pointed out that the color perceptions of a man wearing rose-smoke lenses would be rejected by the present Navy standards for color vision. However, he would be admitted to the submarine service as a low discriminator (10% of the population) on the F-M 100 Hue Color Vision Test.

Dr. Hecht recalled that one of the functions of a sunglass is to protect night vision, and that, therefore, a glass with a higher transmission in the red, such as the rose-smoke, offers more protection of the rods than a blue-green glass with equal total transmission. Dr. Hartline pointed out that the amount of difference could be calculated only by integrating the rod and cone portions of the curve. Lt. Comdr. Peckham made the calculations and reported that rose-smoke has 7.8% rod transmission and 13.4% cone transmission. This is a rod-cone ratio of 10 to 17 or a logarithmic difference of .23.

Lt. Pulling stated that various filters have been used in telescopes and other viewing devices, among them variable-density polarizing, yellow, red, and some neutral lenses. Bureau of Ordnance is interested in reducing the number of filters for such sights and, thereby, the size of the filter housing. A filter or filters that would increase contrast under conditions of haze would satisfy BuOrd needs; Lt. Pulling requested information concerning the properties of haze-cutting filters.

Lt. Verplanck summarized available reports of research on the effect of filters on visual acuity and contrast under conditions of haze (8D, pp. 71-73). He noted that the red dark adaptation goggles have frequently been used as practical haze-cutters.

Dr. Hartline pointed out that rose-smoke should be a better haze-cutter than neutral. This advantage should, however, be weighed against loss of color perception. At present there is insufficient evidence concerning the amount of haze cut by amber and rose-smoke and the degree of loss of color perception on which to base a judgment.

Dr. Miles proposed that the visual effectiveness of filters in haze-cutting or for increasing contrast generally might be improved if prolonged retinal adaptation were avoided. Viewing a field briefly through a colored filter and then through an adjoining neutral of the same percentage transmission would not be a difficult method to apply and would make for prompt judgments by the observer.

In connection with the fact that the selection of rose-smoke from available glasses by the Army Air Forces was based on pilot preference, several members expressed doubt that pilot preference should take the place of scientific determination of the effectiveness of filters and transmission tolerances for stated purposes.

Major Pinson said that the AAF would like to make comparative tests of the rose-smoke sunglass and any neutral glass recommended by the Vision Committee.

The Committee considered the proposed questions in formulating the following recommendations:

1. It is recommended that the services adopt the same requirements for transmission in the flying sunglass and that this transmission be no greater than 15% and preferably less.

2. It is recommended that sunglasses designated for general purpose should be as close to neutral as possible in order to preserve color discrimination and contrast perception at maximum for all colors.

3. In view of the fact that filters for special observation purposes such as haze penetration, air-sea search, horizon viewing or air-snow search, must be designed and tested for the specific conditions of their use, the Services are invited to submit problems of this type to the Committee for study and investigation.

A. THE AAF FLYING SUNGLASS

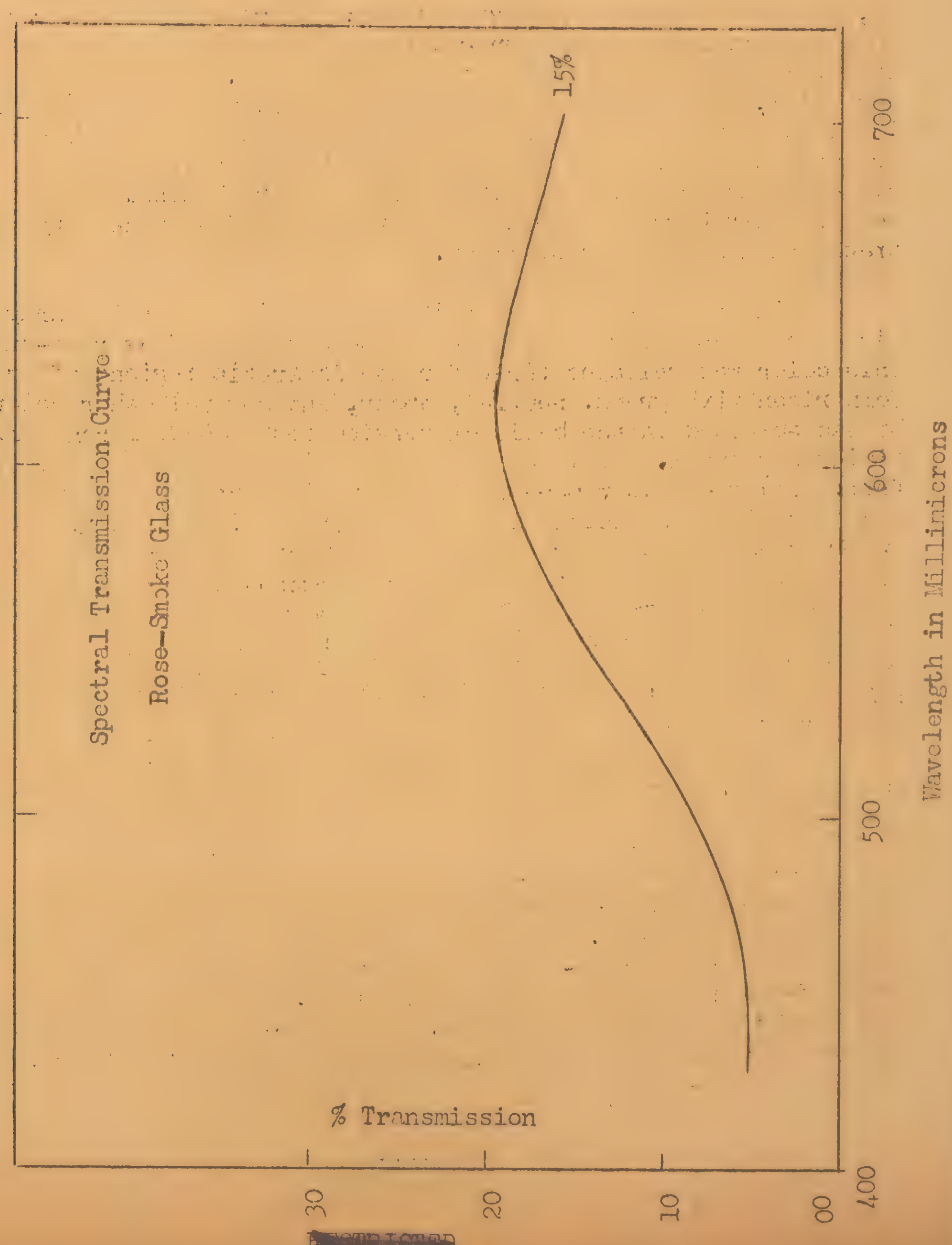
The following is a summary of information presented by Lt. Col. A. P. Gagge and Major E. A. Pinson to the Subcommittee on Sunglasses. It was prepared by Major Pinson.

Glare protection is considered necessary in the Army Air Forces when the illumination against which an air crewman must direct his gaze exceeds 700 to 2,000 foot candles. The brightness of a cloud floor when flying on top is known to be as great as 12,000 foot candles and possibly more. To reduce this brightness to a comfortable value a sun glass which will transmit no more than 15% of incident light is considered necessary. If used at a brightness of 1,000 foot candles, such a glass would reduce the brightness incident on the eye to approximately 150 foot candles which is a brightness well above the point where visual acuity begins to decline to any great extent with decreasing brightness. Consequently the Army Air Forces sun glass was standardized at a density which transmits 15% of incident light.

In the matter of color it was explained that the Army Air Forces was using that which has been described as rose-smoke. This color was selected first for use in Arctic regions after comparison with green, neutral, amber, and several other colors. It was selected on the basis of service test and preference of flying personnel. It is assumed that this preference resulted from: (a) the better penetration of vision through haze which rose-smoke provides and which enables a flyer to pick up enemy aircraft or other objects at a greater distance than would be possible with a neutral or green lens; (b) the enhancement of color contrast between snow and sky in the Arctic and between direct and reflected light which would enable the flyer to distinguish more easily the horizon and to distinguish shadows on the snow; (c) no observed loss in the flyer's ability to distinguish all colors in the spectrum at the high brightness under which the glass is worn even though these colors might not all be equally distinguishable at lower brightnesses.

Since rose-smoke had proven superior for Arctic personnel, it was considered along with green by the Army Air Forces Board when standardization of a darker lens for regions other than the Arctic was undertaken. By comparison with green the Army Air Forces Board found rose-smoke more satisfactory for general glare protection purposes as a flying sun glass. Consequently standardization of this glass was ordered. The rose-smoke glass has now been procured and distributed. No unsatisfactory reports on

color distortion, reduction of visual acuity or reduction of any other visual function have been received to date. Several research organizations in the field, including Central Medical Establishments, have undertaken studies to determine the satisfaction with which rose-smoke was received by combat personnel. In all instances the rose-smoke glass has been commended because of improved penetration of vision through haze and the improved glare protection which it provides. Because of this enthusiastic reception and indorsement by combat personnel, the selection of the 15% transmission rose-smoke by the Army Air Forces Board as the standard flying sun glass for Army Air Forces personnel is considered a well-advised choice.



B. A CRITICAL COMPARISON OF VARIOUS TINTED LENSES FOR AVIATION SUNGLASSES

Lt. Comdr. R. H. Peckham

This Subcommittee has been convoked to discuss the problem of choice of tint and transmission of sunglass lenses. The following glasses have been studied with respect to transmission, color, and availability: (1) green glass, (2) amber glass, and (3) neutral glass.

Green glass has been used in the past for aviation sunglass lenses. This glass is procured from three sources: The Pittsburgh Plate Glass Company, The Bausch & Lomb Optical Company, and the Houze Glass Company. The Pittsburgh Plate Glass Company prepares a glass for the American Optical Company called "Calobar." This is a trade-name indicating the barring of calories. A similar Bausch & Lomb glass is sold under the name "Rayban" indicating the banning of rays. The comparable Houze glass is called "green-tinted" glass. These greenish glasses are approximately 50% transmission although a few lenses have been procured at 35% transmission.

Amber glass has been chosen by the Army Air Forces for standardization in sunglasses. This glass was originally made by the American Optical Company and is prepared by the Pittsburgh Plate Glass Company. It is a frankly orange colored glass of 15% transmission. The name is derived from the generical term "smoke" which is applied in the optical trade to such absorbing sunglasses. The description "rose" is a poetic choice, since the glass does not appear to be of the typical color known as "rose" by artists. A glass similar to this is being prepared by the Bausch & Lomb Optical Company and has been assigned the same name. The Houze Glass Company prepared a special amber glass similar to rose-smoke but of slightly different spectral characteristics. This glass is also being used in the preparation of Army Air Forces aviation sunglasses.

Neutral glass has been traditionally obtained from the Houze Glass Company for many years. The Pittsburgh Plate Glass Company is preparing a modification of the typical nickel and Chrome absorption formula of Houze smoke glass that contains additional elements rendering the glass more nearly neutral for the American Optical Company. The Bausch & Lomb Optical Company lists among its standard available glasses a glass known as N-4, which transmits approximately 15% at 2 millimeters, and a glass known as N-3, which transmits about 25% at 2 millimeters. Both glasses are essentially alike except for the unavoidable increase

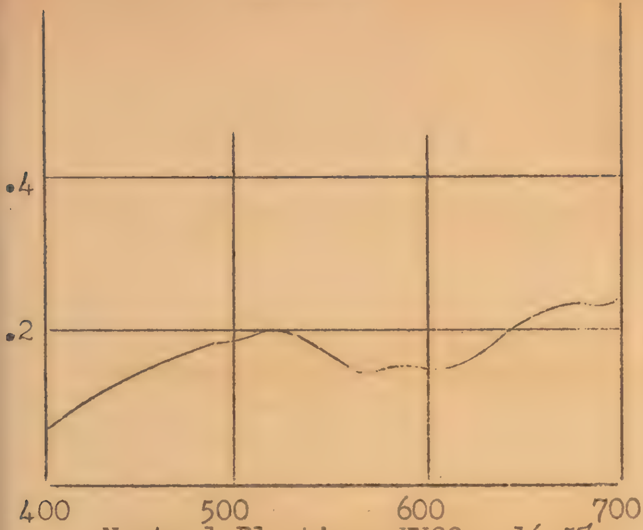
of yellowish color in the darker of the two. The Houze Glass Company has available a glass identified as Smoke No. 1911 in large quantity. This glass contains more color than the other neutrals mentioned above and has 20% transmission at 2 millimeters. The Navy is entertaining the procurement of neutral glass of 20% at 2 millimeters.

Spectrographic curves of such glasses are illustrated in Fig. I. Comparison of these glasses at the same transmission value is necessary in order to study their effective color distortion. The reduction of transmission from the thicknesses illustrated in the spectrograph to comparable density is accomplished by multiplying the transmission at wavelength intervals of 10 millimicrons by the reflection factor of 1/92%, reducing this transmittance to density by taking the logarithm of its reciprocal, multiplying this term by a factor sufficiently great to accomplish the necessary transmission (this factor can be estimated roughly from the known visual transmission of the sample.) This new density is then converted into transmittance and multiplied by 92% to yield transmission. Figure II shows the spectrographs of these glasses reduced to approximately 20%.

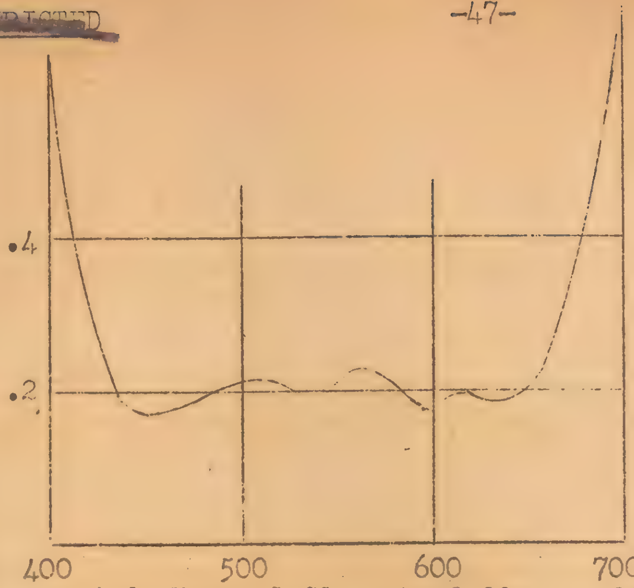
The Munsell values of these 20% samples have been computed and are shown in Table I.

An approximation of the effect of neutrality of these glasses can be found by plotting the tri-stimulus curves for Illuminant "C." By inspection, a comparison of the various glasses will yield an estimate of the degree of distortion. In this manner, the glasses have been arranged in the order of their expected neutrality as shown in Table I. An index of neutrality should be devised to study these glasses since the statement of Munsell color does not of necessity indicate the degree of color distortion. This is illustrated by the comparison of the rose-smoke with the polarizing tracer-search filter in the table. The tracer filter is more nearly neutral but because of the irregularity of its spectral curve, it actually distorts color more than rose-smoke. The author is trying to devise a method of expressing a neutrality index. If such a method is devised, it will be the subject of a subsequent report.

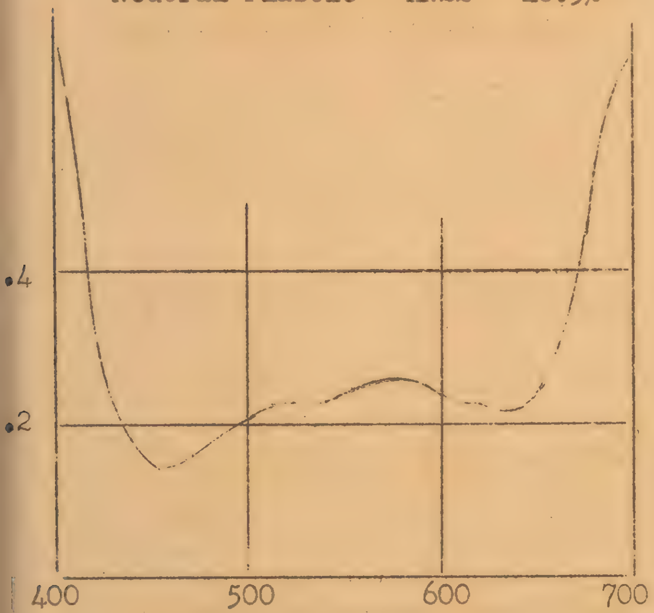
In considering the availability of neutral glass, it should be pointed out that glass requires about six weeks to three months for preparation, if the exact formula is known for large batches. A new glass requiring a special formula will require from one to four months of experimental work before large batches can be produced. With this in mind, it is therefore necessary to select glass which is either already made or which is a standard product,



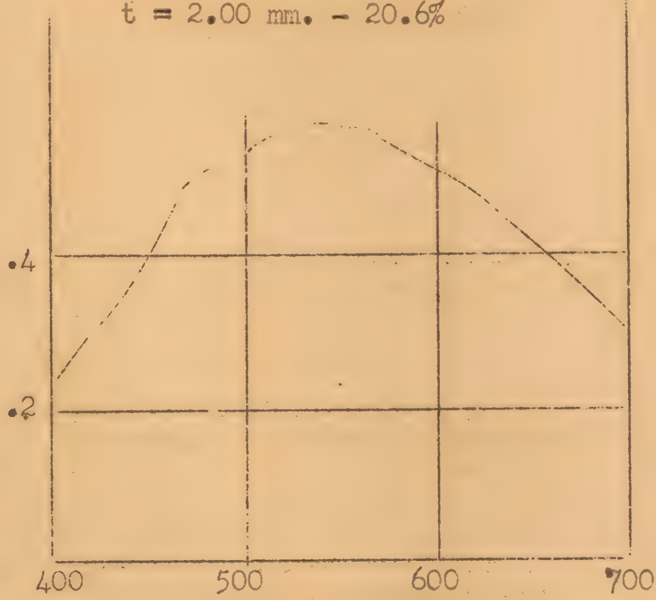
Neutral Plastic - XN22 - 16.5%



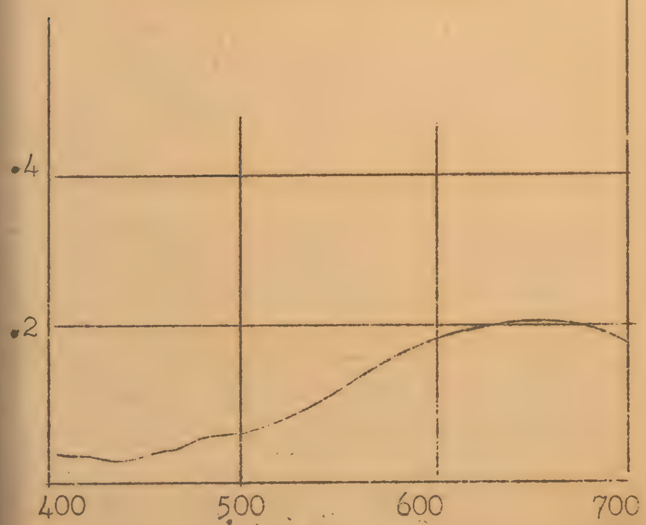
A.O. Neutral Glass t= 2.00mm. - 20.6%
t = 2.00 mm. - 20.6%



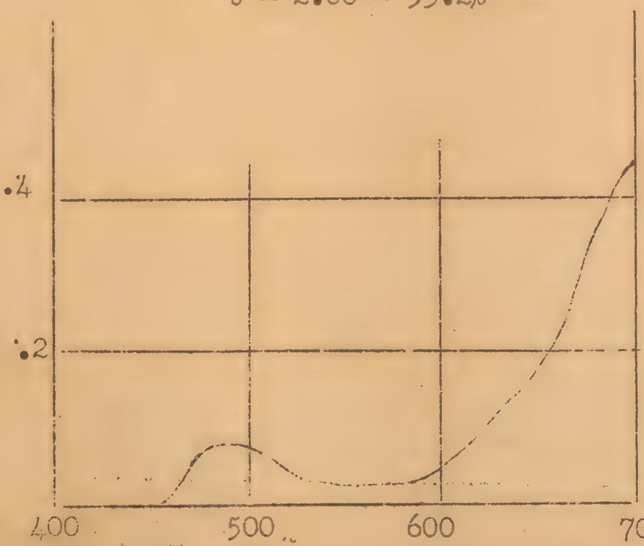
Houze Smoke 1191
t = 1.63 mm. - 25.3%



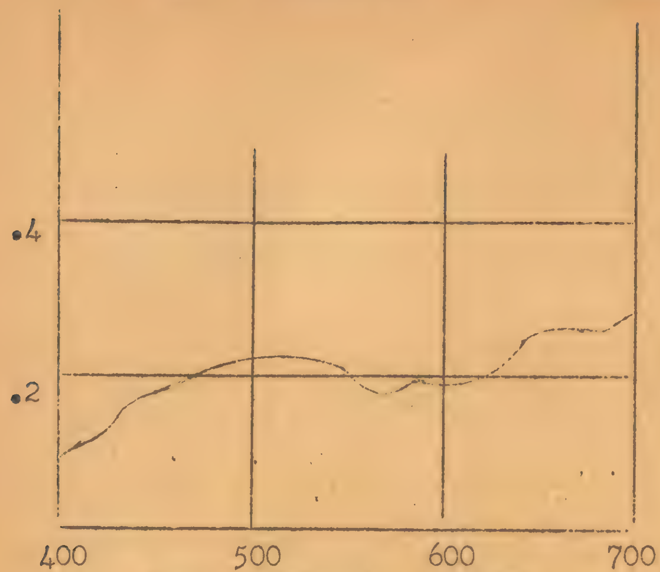
Calobar "C"
t = 2.00 - 53.2%



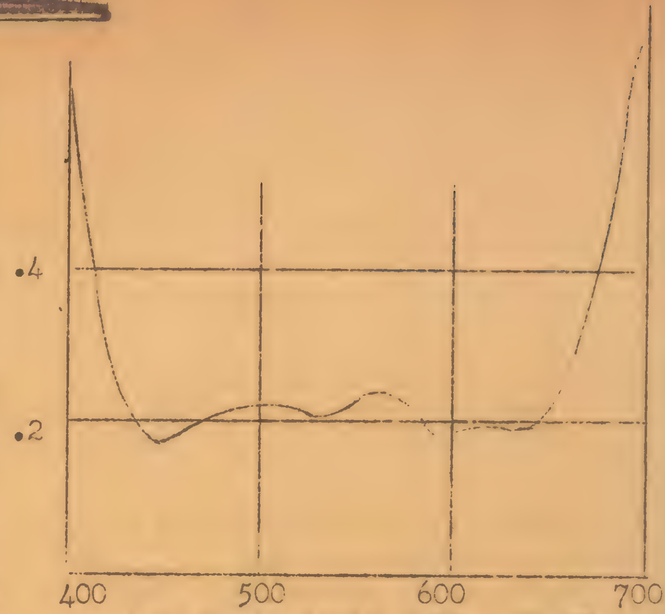
Rose-Smoke
t = 2.11 - 13.4%



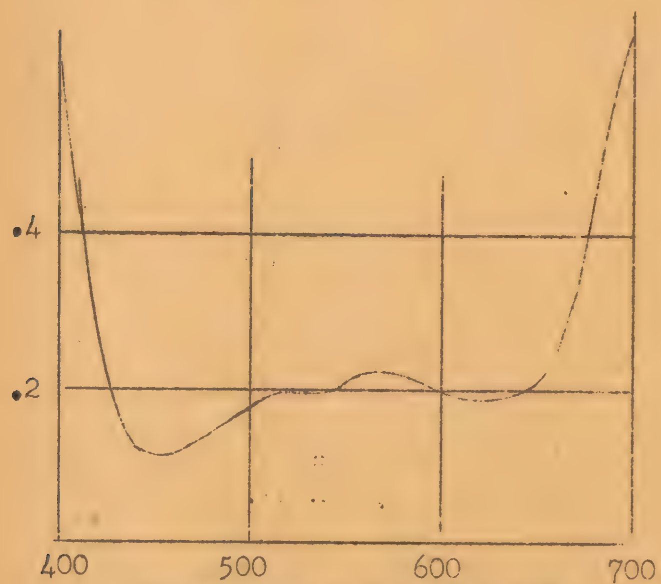
Tracer-Search Plastic - 4.2%



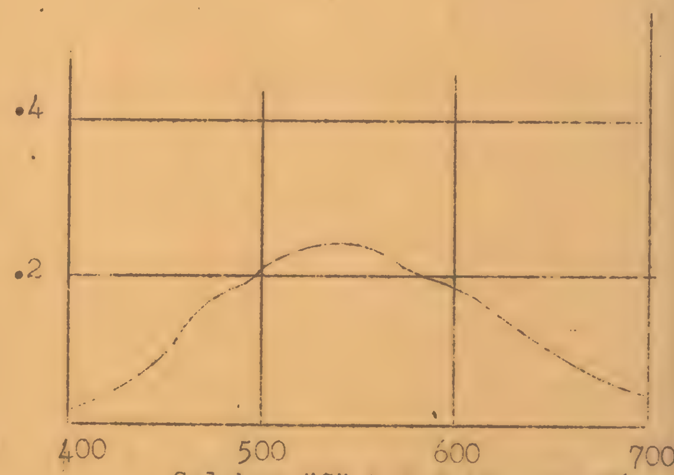
Neutral Plastic - 20.0%



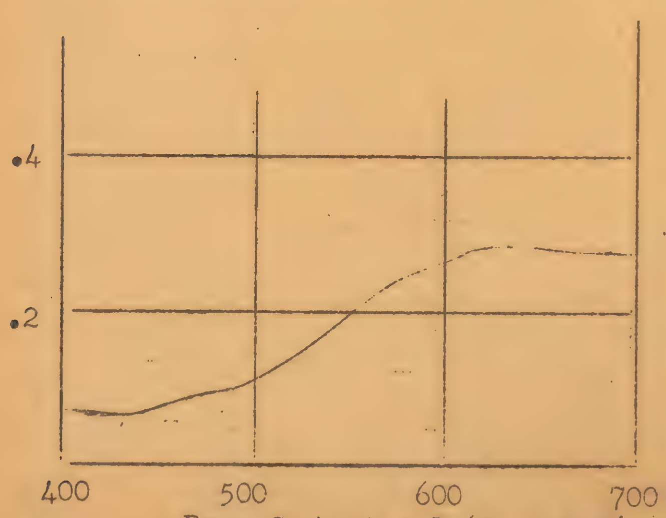
A.O. Neutral t= 2.01 - 20.0%



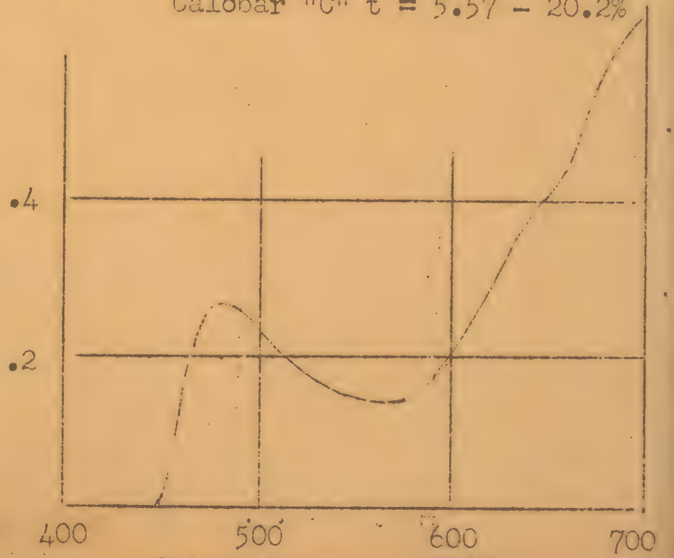
Houze Smoke t = 1.93 - 20%



Calobar "C" t = 5.57 - 20.2%



Rose-Smoke t = 1.67 - 18.8%



Search-tracer - 18.6%

TABLE I

Comparison of Tinted Sunglasses at 20%

Material	t of sample mm	Transmission of sample %	t at 20% mm	Munsell chroma at 20%	Approximate rank order of neutrality
XN22	*____	16.5	*____	/1.0	1
A. O. neutral	2.00	20.6	(2.01)**	/0.3	2
Houze smoke	1.63	25.3	1.93	/1.8	3
Calobar C	2.00	53.2	5.57	/5.5	4
Rose-smoke	2.11	13.4	1.67	/5.5	5
Tracer-search	*____	4.2	*____	/3.6	6

* Plastic material - the density is controlled by concentration of dyestuff at 0.030 inches thickness.

** Correction of thickness disregarded as too small.

when it is desired for immediate procurement. On the other hand, plastic materials can be prepared in quantity upon a notice of three weeks to a month from the first expression of the desire for the material to the final mass production of the materials.

Rose-smoke glass has been specified with respect to the spectral transmission of the first samples produced by the American Optical Company. The amber glass produced by the Houze Glass Company similar to this requires a second specification since, although the glass matches the color, it does not match in exact spectral transmission. The Bausch & Lomb Optical Company has succeeded in producing a rose-smoke in small quantities that is spectrally comparable to that produced by the Pittsburgh Plate Glass Company for the American Optical Company. About 35,000 pounds of Houze Smoke #1911 is immediately available. The Pittsburgh Plate Glass is at present rolling sufficiently large quantities of American Optical neutral glass. Bausch & Lomb N-4 or N-3 can be produced when required.

Following the production of the glass, the problem of manufacturing enters. Three major companies; the American Optical Campany, the Bausch & Lomb, and the Charles Fisher Spring Company together produce approximately 100,000 to 120,000 pairs per months. However, the replacement of 200,000 pairs of lenses, as is being considered by the Navy, will require from three to nine months for completion depending upon the rate polishing laps become available from the already established procurement of rose-smoke glasses for the Army Air Forces.

For this reason, the Navy is considering the feasibility of producing neutral plastic lenses for aviation sunglasses of approximately 25% transmission for immediate replacement of the present 35% to 50% Calobar and Rayban lenses. As soon as these plastic lenses wear out, they may be replaced with fresh plastic lenses until glass lenses become available.

From the information available to date, determined from the spectral characteristics of the glasses with respect to the ICI estimates of psychological response to spectral color, it would seem that the least color distortion would be afforded by a neutral glass and that the Navy choice of neutral glass at 20% would yield less color distortion than the Air Forces choice of rose-smoke at 15%.

C. THE EFFECT OF COLORED GOGGLES UPON COLOR DISCRIMINATION

Lt. Dean Farnsworth

SUMMARY

Six pairs of goggles with tinted lenses were used in several laboratory tests to determine the effects on color perceptions during and after the wearing.

1. The general conclusion is that the more neutral the glass, the less the distortion of color relations. The glasses would therefore rank in the following order of desirability when adjusted for equality of total transmission:

First - Bausch & Lomb "Neutral" (slightly greenish)

Second and Third - Calabar "C" and "D" (greenish)

Fourth - Polaroid "HN12-d" (appears neutral but is two-color transmitting)

Fifth - "Rose-smoke" (reddish-orange)

Sixth - Noviol (strong yellow)

2. The gray-green group of glasses (first, second and third in the above list) caused no more reduction of color perception than is found in "low-discrimination" normals. The rose-smoke glass simulated the vision of a person who is on the "borderline" of color deficiency, and the Noviol glass induced color relations of the kind evinced by colorblinds.

3. After-effects diminished in a few seconds. Observations taken within 5 seconds after removal of the glasses indicated discrimination limens intermediate between those of glasses and the naked eye.

4. The tests indicate that acceptable color limits can be stated as equivalent to about 3 Chroma steps at middle Value (Munsell nomenclature) assuming smooth spectral distribution, or by the corresponding Judd duplication index.

DISCUSSION

The problem of selection of color for sunglasses is an extremely complex one. To approach it in the simplest terms, sunglasses that are completely neutral present no chromatic problem. Since it is difficult for the manufacturers to turn out neutrals closely to specification, the problem is to determine the amount and kind of deviation from neutral that can be permitted, keeping in mind that the particular spectacle selected will be used over an extremely wide range of color conditions.

First of all, we can remember that the appearance of colors as seen through tinted goggles can be treated by the same techniques that would be used if we were examining surface colors under different colored lights. It does not matter whether the filter is put over the illuminant or put over the eye. Secondly, we must expect the eye to show an amazing adaptability to changes in the color of illumination. Deane B. Judd (J. O. S. A., January 1940) noted that "The visual mechanism of a normal observer is so constructed that objects keep nearly their daylight colors even when the illuminant departs markedly from average daylight. The processes by means of which the observer adapts to the illuminant or discounts most of the effect of a non-daylight illuminant are complicated." Depending upon the conditions, the adaptation is largely accomplished in from less than 1 to 5 seconds.

We know in a general way what effect a light of pronounced hue has upon a color series--red, yellow, green, blue, purple. The general formulation can be diagrammed as a constriction of the color circle into an elipse, the minor axis of which represents the reduction of chromaticity discrimination. Unfortunately, there are a variety of psycho-physical factors which vastly affect this simple tendency.

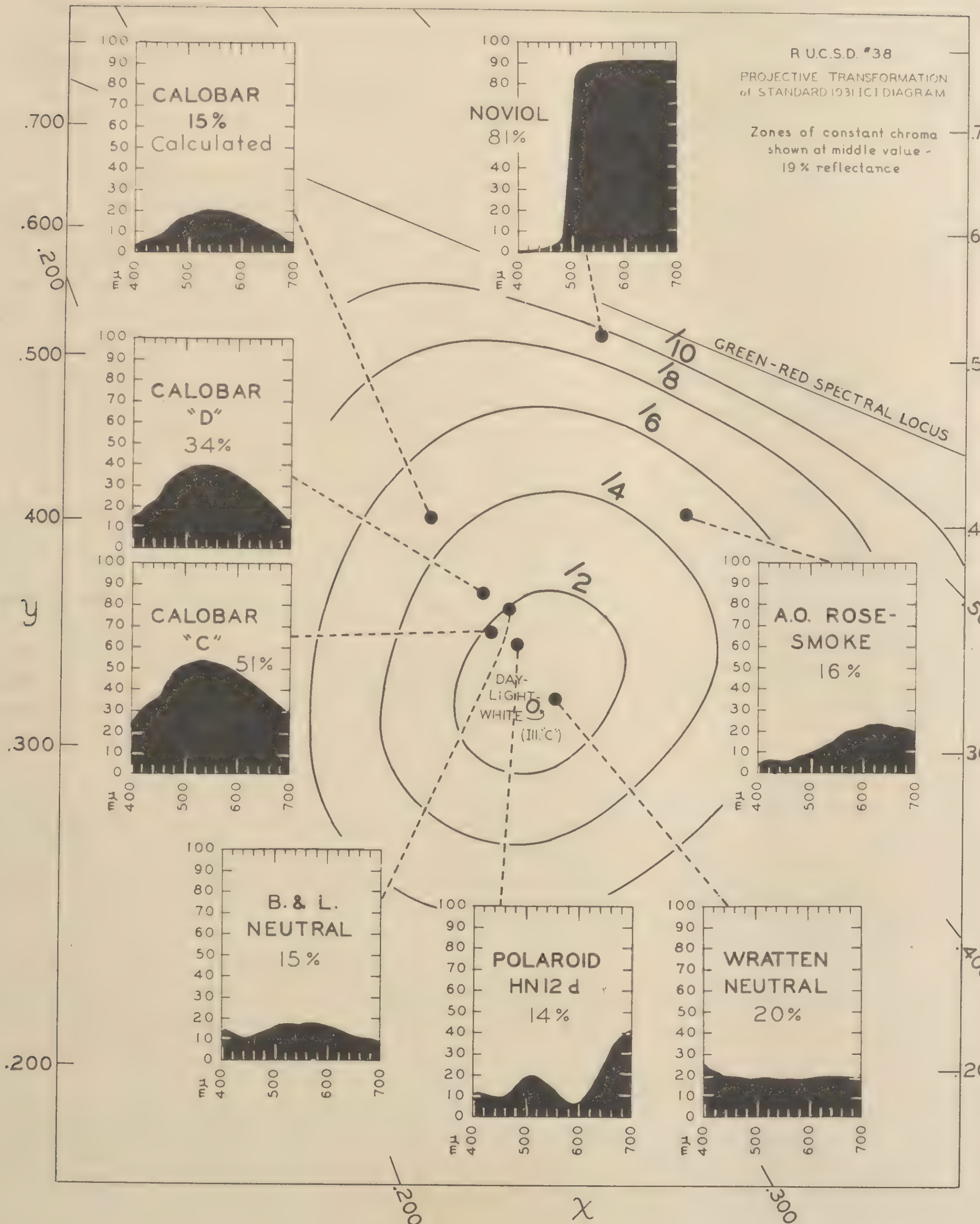
1. Goggles reduce brightness, and one effect of reduced brightness is that the light and dark objects in a visual field tend to take on the color of the illuminant and the complementary to the color of the illuminant, respectively.

2. When we are dealing with small-difference perception of color, the individual differences between observers' eyes have a marked effect on the results. These differences are due, at least in part, to differences in retinas, coloring of the ocular media, and to macular pigmentation.

3. There are the highly complex interrelations resulting from variable spectral characteristics of all the media and colorants involved. This makes every situation a new problem.

COLORED GOGGLE LENSES

1. Spectral Transmittance
2. Per Cent Transmission to Ill. C
3. Chromatic Position on Munsell Curves of Constant Chroma



The experimental problem was how to reduce the overall picture to general states, eliminating the extremes, in an effort to make useful generalizations. One extensive approach was conducted by J. D. Reed, PhMlc, by the method of matching the film colors in a bi-part field. The variables consisted of liquid wedges which were matched to standards of the same spectral characteristics. (Method of Average Error.) The standard deviation of the observers' matches for each color of goggle was taken as an indication of his chromatic sensitivity in the color ranges of the wedges. Results indicated that the reduction in sensitivity to small color differences caused by the tinted goggles were usually less than the differences between observers, and not much in excess of that caused by a neutral filter.

Inspection of the data shows a high retest reliability for a particular observer for a particular goggle (differences between sets of observations were not over 11%) but shows a greater difference between observers making observations under identical test conditions. (These differences are of an order of 40% to 80%.) There is no apparent correspondence between the saturation of the glasses and the accuracy of the match. The apparent inconsistencies may be due to unanalyzed spectral characteristics but may be due also to an extreme extension of the faculty of adaptation to very small color differences.

A more direct method was to use the glasses on standard color tests for normal vision. One of the tests used was the author's Dichotomous Test (J. O. S. A., October 1943) which was designed to indicate a reduction in chromatic discrimination of 80% or more. One goggle, the Noviol, induced an effective color blindness in the observer by the above definition. Rose-smoke, which was about 1/2 as far removed chromatically from the neutral, interfered with judgment, but did not prevent the observer from setting up the colors in normal array. The gray-green group of goggles proved no handicap at all.

A more sensitive test is the F-M 100 Hue which was designed to detect slight deviations from normal vision. The wearing of Noviol glasses gave a test pattern very similar to that of a blue-yellow blind. The rose-smoke showed significant deviations equivalent to partial violet-greenyellow blindness, and the gray-green group made less difference to the observers' vision than is found between normals and the common low-discrimination type of color vision.

There were several important or interesting by-products of the experimentation:

First, the difference between observers. It would seem that the differences in color vision due to wearing the gray-green group of lenses would be less than the differences which exist

between normals and the low-discriminators, or between normals and the mildly anomalous.

Second, the uniformity of spectral transmission of the glasses. While there are four glasses that fall in almost the same chromatic region, three of these glasses exhibit regular spectral transmissions. The fourth, Polaroid H12-d, is highly dichroic, exhibiting two peaks of transmission, one in the red and one in the blue-green. This gave highly erratic results not predictable in simple formulation but which were dependent upon the particular spectral characteristics of each individual thing observed. The effects would be highly susceptible, for instance, to the peculiar characteristics of chlorophyll, haze, etc.

Third, the readaptation period. It might be assumed that while the eye could adapt to the continuous use of goggles that the readjustment period upon taking them off would present special difficulties of adjustment. One experiment was devised in which a judgment could be made within 5 seconds of removal of the goggles. The standard deviations of these judgments were almost consistently intermediate between naked eye observation and full adaptation to the goggle.

Fourth, differentiation due to selective transmission. Any increase in apparent differences between certain colors obtained from the color of goggles is more than countered by a greater reduction of perception in other color regions. For instance, under certain circumstances, rose-smoke may somewhat bring out the differences between cloud shadows and sky, but will greatly reduce the perception of water depths which consist of a series of greens.

METHODS OF SPECIFICATION

It would seem that the further a filter deviates from a neutral with smooth transmission characteristics, the less reliable, on the whole, will be the observers' impression of the world. For a rough formulation of the degree of deviation to be permitted in manufacture, it can be assumed that the spectral purity or chroma represented by the gray-green group of glasses will probably induce no greater variation of sensitivity than that normally found among observers in the Services. These glasses are equivalent to Munsell Chromas of 1 to 3 at middle Value.

The above description is too loose for commercial specification. The Bureau of Standards suggests the use of a duplication index described by Dorothy Nickerson (Ill. Engr., March 1941)

based on values defined by Judd (J. O. S. A. 29, 145, 1939.) "Color differences are indicated by taking differences of apparent reflectance, Y, and trilinear coordinates, r, g, b, for the uniform-chromaticity-scale (UCS) triangle." In a modification of the Judd method, Nickerson uses the chromatic index separately so that "the sum of the deviations for r, g and b are an index of the degree to which the chromaticity relations...may be expected to remain constant..."

"It is probable that a satisfactory degree of freedom from object-color distortion by a goggle lens could be insured without undue arbitrary restriction of the spectral characteristics of the lens by specifying a limiting value of the duplication index, I_d, in purchasas of such lenses."--Bureau of Standards report, May 14, 1945

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9. THE ARMY GROUND FORCES NIGHT VISION PROGRAM

Major L. O. Rostenberg

BACKGROUND

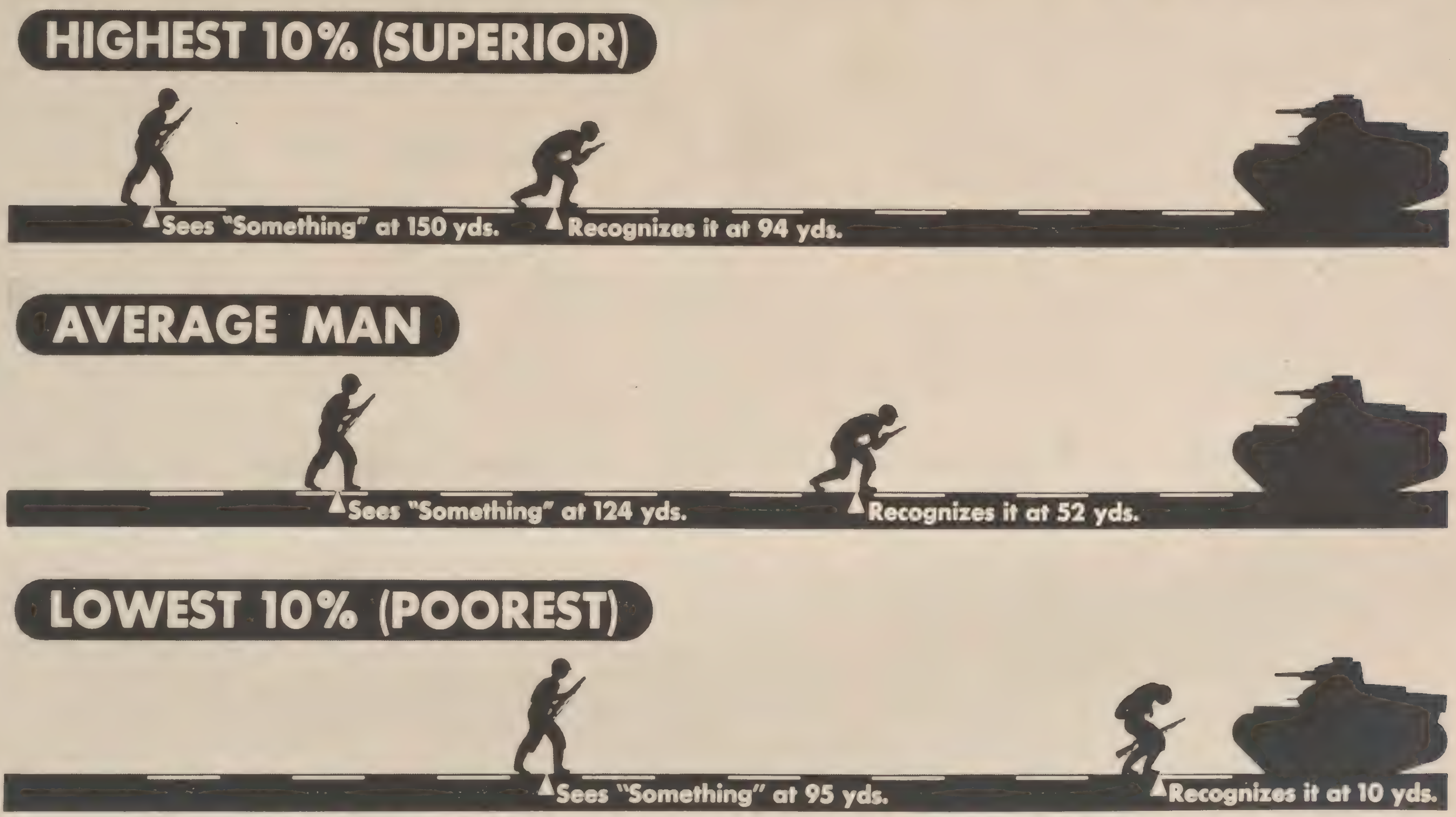
Army Ground Forces training programs since before the present war have included night training. This training did not, until very recently, recognize or consider the factor of night vision in night operations and combat. Night vision training, as such, did not exist. It was only last year that night vision was first written into a training manual for ground forces use.

Probably the first Army Ground Forces component to attempt seriously to investigate night vision in relation to ground forces military activities was the Field Artillery School, Fort Sill, Oklahoma. Systematic night vision research was organized there in 1942, which resulted, in 1943, in the successful development and validation of a highly reliable, simple, group night vision tester that could be built with the tools and within the resources available to the average field unit. It made possible large-scale, accurate testing and preselection of personnel for night operational duties on the basis of their night vision abilities — assigning men with superior night vision to vital night duties, and those with poorest night vision to least important duties.

The validation studies at Fort Sill resulted in reliable outdoor criteria, which also appeared to be useful as excellent outdoor night vision training exercises. The great individual differences between soldiers in their night vision ability was noted and measured (see Figure 1). To confirm the Fort Sill results, larger scale tests were conducted at the Infantry Replacement Training Center, Camp Blanding, Florida, early last year, using the Field Artillery School equipment and techniques. Not only were the Fort Sill results confirmed, but the IRTC training authorities were also able to observe and evaluate instructional and training values of both the outdoor procedures and the indoor test. It was indicated that night vision training could be integrated into usual night combat training, both to increase efficiency of such training and possibly save training hours.

As a result of these successful experiences, the Adjutant General's Office, the G-3 training section of the War Department General Staff, and the Army Ground Forces, by last summer, considered favorably an Army-wide night vision testing-training and classification program. For several reasons, however, principally because most of our troops were overseas by last fall, and also because of non-

DIFFERENCES BETWEEN SOLDIERS IN ABILITY TO SEE AT NIGHT



SOLDIERS SELECTED AND TRAINED IN NIGHT VISION HAVE A LIFE-OR-DEATH ADVANTAGE OVER THE AVERAGE ENEMY

agreement as to where testing would be done - at RTC's or Induction Centers - the Army-wide program did not materialize. However, immediate preparation and dissemination of a new night vision circular was decided upon, in which the Field Artillery School Night Vision Tester-Trainer (ANVTT) was to be described and designated as a standard Army night vision test.

INITIATION OF PRESENT PROGRAM

For some time, numerous observers have reported night combat a major problem in all theaters. Attempts had been made in the field to meet the problem, but lack of knowledge concerning night vision had limited the results. Recently developed night vision and other techniques have made possible much more efficient night combat. The theaters have made known their interest in night vision. The ability to select "cat-eyed" men for special night operations seems of particular interest. The redeployment training program heavily emphasizes night combat training.

Upon War Department directive, Army Ground Forces, in April of this year, directed that the Replacement and School Command train twelve "Night Vision Testing and Training Demonstration Teams" at the Field Artillery School, Fort Sill. Because of a personnel problem, the location was later changed by the Replacement and School Command to the Armored School, Fort Knox. Provision of the Army Ground Forces directive included:

1. 4 teams to be trained to meet overseas requirements;

2. 8 teams to be trained to provide one team for each of the Army service schools;

3. teams to consist of 3 officers and 2 NCO's;

4. course of instruction to be about 15 days;

5. readiness dates to be June 1 for overseas teams and July 1 for school teams;

6. training to be conducted under supervision of the writer;

7. the Army Night Vision Tester-Trainer to be built locally in the training aids shops.*

*Constructing ANVT-1, T-6212, Tactics Department, The Armored School, Fort Knox, Kentucky (Restricted), gives the step-by-step procedure for construction and may be obtained from The Armored School, Fort Knox.

MISSION OF THE NIGHT VISION TESTING AND TRAINING DEMONSTRATION TEAMS

As the name implies, these teams are organized to demonstrate night vision testing and training to theater commanders and at the service schools in the United States. Their mission is generally as follows:

1. Demonstrate the use and value of the Army Night Vision Tester-Trainer as a means for classifying soldiers as to their night vision ability and the value of such classification in making key night assignments.

2. Demonstrate the great natural differences among individuals in their ability to see in the dark.

3. Explain and demonstrate how efficiency of troops operating and fighting in darkness may be materially increased by proper use of night vision.

4. Demonstrate value and use of proper night vision aids, such as proper red lights, binoculars, dark adaptation goggles, and radium markers, etc.

5. Explain and demonstrate how night vision training can be integrated into present night combat training, giving consideration to new combat techniques and equipment, such as artificial moonlight, infrared devices, electronic aids, radium activated markers, etc.

6. Assist in setting up training programs for training special units in combat organizations to specialize in night operations.

It should be noted that this program does not consider night vision as a medical problem.

PROBLEMS INVOLVED IN SETTING UP PROGRAM

The program started under heavy obstacles. Among the problems were:

1. Lack of trained personnel familiar with the Fort Sill and Camp Blanding work, on which the Army Ground Forces program is primarily based. It was found that all of the original Fort Sill and Camp Blanding personnel were overseas and only the writer available in the United States.

2. Shortness of time to prepare instructional material and train instructors.

3. Lack of equipment: only the few original Fort Sill instruments were available.

4. General lack of knowledge concerning night vision throughout AGF echelons.

SCOPE OF NIGHT VISION INSTRUCTORS COURSE

The course of instruction designated as Night Vision Instructors Course No. 1 commenced for officer students on 10 May, and for enlisted students on 15 May. Concurrent and subsequent additional instruction gave both enlisted men and officers about an equal amount of training. Each team member is trained to function efficiently in the duties of every other team member. In course No. 2, started recently, both officers and enlisted men take the same instruction and subjects.

The course of instruction for the Night Vision Instructors Course is outlined in Program of Instruction for Night Vision Instructors Course, 30 May 1945, Hqs., The Armored School, Fort Knox, and Night Vision Instructors Course No. 2, first week (4-9 June 1945); second week (11-16 June 1945), Hqs., The Armored School, Fort Knox.* The course is designed to give the future instructors a much more thorough knowledge of night vision and its underlying principles than is considered necessary for instruction of troops. Much practical work is included, mainly planned around the Army Night Vision Tester-Trainer and the simple outdoor training procedures. Indeed, about one-half the hours of instruction are supervised practical exercises, simulating as far as possible actual field conditions, and designed to fit teams for their mission - how to get around and get a job done.

When graduated, teams are provided with full equipment, complete training literature, "sales kits", and detailed instruction designed to meet all foreseeable contingencies. They have been instructed to stick to fundamentals and to keep everything as simple as possible.

OPERATIONAL PROCEDURE FOR TEAMS

The following is the recommended procedure for conduct of Night Vision Testing and Training Demonstration Teams in overseas theaters:

1. "Upon arrival in the overseas theater, Night Vision Testing and Training Demonstration Teams will report to the Theater Commander. Under the direction of the Theater Commander these teams will

*These schedules (Restricted) may be obtained from the Office of the Secretary, Army-Navy-OSRD Vision Committee or The Armored School, Fort Knox, Kentucky.

conduct night vision tests and demonstrations for appropriate selected personnel. From this selected personnel additional teams will be trained.

2. "Personnel of teams developed in this manner will be returned to the lower echelons of the command. There they will conduct tests, demonstrations, and training for personnel selected from still lower echelons. This training will be identical to that conducted by the original teams.

3. "The above process will be continued until all echelons of the command have an adequate number of night vision teams to test and instruct sufficient personnel to engage in night combat as is prescribed by the Theater Commander. When this has been accomplished personnel of the original teams will be utilized in whatever manner the Theater Commander may direct.

4. "At the same time the procedure recommended above is presented to the Theater Commander or his representative, team captains will acquaint him as to the capabilities and limitations of the team. Each team captain must realize that the final disposition and use of the team rests with the Theater Commander, and his decision will be based largely on the team commander's initial presentation of facts."

Procedure for teams going to the Service Schools has been recommended and approved as follows:

"Each team assigned to a Service School will under the direction of the Commandant:

1. "Advise and assist in incorporating night vision training into all training and instruction to which it applies.

2. "Conduct night vision tests of school and student personnel.

3. "Provide the nucleus of instructor personnel for, and assist in the organization of Night Vision Course at the Service School. The mission of the course will be to train additional Night Vision Testing and Training Demonstration Teams for assignment to replacement training centers, in the event that night vision training is included in the program of instruction at replacement training centers."

RESULTS THUS FAR ATTAINED

1. Four teams and an alternate fifth team of five officers and enlisted men have been thoroughly trained. These teams are about

to embark on their overseas mission.

2. Eleven instructors have been trained and are now carrying on the instruction of the second class.

3. A small pool of additional officers and enlisted men have been trained in night vision and are available as alternates or future team members.

4. A second class of 44 officers and enlisted men is now undergoing training.

CONCLUSIONS

1. It is considered that as yet we have made only a start.

2. Results cannot yet be predicted. Performances of teams will probably determine the future of night vision testing and training in the Army Ground Forces. Adoption of testing and training in theaters depends on overseas teams, and expansion in the United States depends upon results obtained in service schools.

3. Much research still needs to be done; AGF cannot do it.

4. Rate of testing will doubtless influence adoption of a theater-wide or Army-wide program. The present rate of testing is 16 per hour per ANVTT unit but there is an excellent possibility of increasing this rate to 24 or 48 men per four per instrument without an increase in administration personnel. Teams at present can test at a rate of 360 to 540 men per day when augmented by a small cadre of assistants from units tested.

5. While commercially built equipment would be highly desirable, it is considered that the long time necessary to obtain it precludes any attempt to do so. Hence, it is contemplated that units will be built by AGF installations in their training aids sections or facilities, either by supplying essential components to field units or complete "knockdown" sets.

6. The present program is under G-3 (Training) of AGF, which properly is concerned mainly with training. Therefore, impetus for Army-wide testing will have to come from elsewhere although it has been found that in night vision, testing and training are virtually inseparable.

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10. RELATIONSHIP OF INTERPUPILLARY DISTANCE TO PERFORMANCE ON THE ORTHO-RATER

Lt. J. H. Sulzman

SUBJECT

The relationship of interpupillary distance to performance on the Ortho-Rater phoria slides is complex, and in order to clarify the subject, some definitions are required.

DEFINITION OF TERMS

Normal muscle balance is the condition in which the visual axes of the eyes are parallel when the extraocular muscles are in a state of functional rest, as when binocular fixation is suspended.

Binocular fixation is a term used to indicate that there is simultaneous viewing of an object by both eyes. It implies that there is no manifest strabismus and that any latent ocular imbalance is overcome.

Binocular single vision signifies that when binocular fixation is employed, there is neither suppression of one eye nor double vision. It is often used interchangeably with binocular fixation.

Superimposition is a term used to imply binocular single vision when dissimilar objects are viewed by each eye. It is a function of the macula primarily.

Fusion is a term which is often confused with superimposition, but which implies more than the latter. Not only are the main points of fixation welded into a composite whole image, but portions of the visual field which are perceived extra-macularly are likewise blended into a single impression.

Depth perception is the highest degree of binocular vision. Not only are the preceding grades of the visual funtion necessary, but in addition, points in front of and behind the point of fixation are fused into an impression of the relationship in space which they bear to one another in the field of view.

PRELIMINARY DISCUSSION OF TESTS USED FOR DETERMINING MUSCLE BALANCE.

The object of all tests for muscle balance is to measure the amount of deviation of the visual axes when the extraocular muscles are in a condition of maximal rest.

It is axiomatic that binocular single vision is a natural impulse. Conversely, double vision is disposed of, either consciously by striving for binocular fixation, or, if this be impossible, by the unconscious suppression of one image. When it is realized that the eyes are in constant motion, either rotating horizontally, diagonally, or vertically as surroundings are viewed, or converging and diverging as near and distant objects are fixated, it can be appreciated that the extra-ocular muscles receive almost constant stimuli.

Such being the case, it is not surprising that normal muscle balance, as defined previously, is the exception and that some degree of ocular muscle imbalance is the rule. It is clinical experience that some heterophoria, that is to say, latent ocular muscle imbalance, can be demonstrated in nearly everyone, depending upon the sensitivity of the test employed.

This point is made in an excellent report (Project No. 375, Report No. 1, dated 13 April 1945) by Captain Scobee of the AAF School of Aviation Medicine, Randolph Field, Texas.

It is agreed generally that the determination of the direction of the visual axes when fusion is interrupted may be regarded as the best measurement of the position of rest of the extraocular muscles. The most satisfactory test for muscle balance should be one which is both sensitive with regard to the demonstration of small deviations, and easy to administer. At the same time, it must yield reasonable test-retest reliability. Opinions vary with respect to the relative merit of available tests when these criteria are applied.

CLASSIFICATION OF TESTS FOR OCULAR MUSCLE BALANCE

In general, tests for ocular muscle balance may be divided into four categories. There are many tests, the complete list is too lengthy to be considered in this paper.

1. Displacement tests

A. Diplopia "E" tests. A 20/100 Snellen letter E is illuminated as the test object for both eyes at a distance of 20 feet. Insuperable vertical diplopia is created by placing a 5 or 6 prism-diopter prism base down before one eye.

2. Distortion tests

A. Maddox rod. A white or red glass rod, single or multiple, and mounted on an opaque disc, refracts in only one meridian at a right angle to the long axis. In consequence, a point of light, viewed through the rod placed before one eye, is seen as a line of

light, while the unobstructed eye sees the actual light source. However, the maddox rod does not produce sufficient distortion of the light to overcome the impulse to superimpose the line on the light.

B. Sight Screener. Right eye sees a horizontal row of letters, left eye sees a vertical line which appears to intersect them.

3. Cover Tests

A. Screen and parallax test. A 1 cm light is used at 20 foot distance. An occluder is shifted from over one eye to the other, loose prisms being changed behind the cover until (1) movement of the eye to fix when uncovered is neutralized objectively and (2) apparent movement of the light is neutralized by the subjective interpretation by the patient.

This test is tiring and requires considerable cooperation and skill. Objective eye movement ceases usually before the patient reports the subjective cessation of movement of the light, and thus a source of considerable error may be introduced.

4. Combination tests

These are generally used and are most accurate.

A. Maddox-Screen test. This is prescribed for the examination of candidates for flying by both Army and Navy. As indicated by the title, it combines the features of distortion by use of the Maddox rod and cover tests.

B. Telebinocular. Right eye sees a horizontal row of dots, left eye sees an arrow below their level. This instrument combines the displacement and distortion principles.

C. Ortho-Rater. Right eye sees a horizontal row of dots, left eye sees an arrow pointing upward at the middle one of three dots. These dots seen by the left eye give a slight fusional effect with those seen by the right eye and tend to minimize shifting of the arrow.

This instrumental method combines displacement and distortion principles, with a slight fusional aid.

It can be seen from the foregoing discussion that each test for lateral muscle balance which has been considered varies in some significantfeature from each of the others. As Captain Scobee has expressed it: "Various tests of heterophoria yield varying results

in the same individual because varying numbers of innervational factors are eliminated by each of the different tests."

When tests for muscle balance are considered, the distance from the target enters into the situation. When tests are conducted at a distance of 20 feet, accommodation is called upon to only a slight degree, if at all. However, tests performed at a distance less than 15 feet must allow for the convergence which normally accompanies accommodation for near vision.

The manufacturers of visual screening devices which employ tests for lateral muscle imbalance neutralize this demand on accommodation and convergence by inserting decentered convex lenses which relax accommodation and convergence to the optical equivalent of distance tests. However, the person being tested realizes that the distance from the targets is a near one, and hence the term "instrument effect" is used to describe subconscious attempts of accommodation and convergence.

Nevertheless, it is the function of such optical systems to make parallel, rays of light emerging from the exit pupil of the instrument. Thus the direction of the rays of light will be constant regardless of the position of the eyes or the interpupillary distance.

Finally, the question of interpupillary distance may be considered briefly. The relationship of this factor to the determination of lateral muscle imbalance is apparent when it is appreciated that a person with a wide IPD will have to converge his visual axes more to fix binocularly an object at 13" distance from the eyes, than will another person with a narrow IPD. Attempts have been made to correlate IPD with lateral muscle imbalance and this has been evaluated during the course of ocular tests at New London.

The clinical method for measuring IPD employs a millimeter rule aligned by the observer's eye. More accurate measurements can be obtained by means of the NDRC Interpupillometer, which employs a vernier measurement. This latter method has an extremely high coefficient of correlation for test-retest values, and data therefrom are described by a normal frequency distribution curve.

The Ortho-Rater also has a good coefficient of reliability for lateral phoria test-retest, and its data fit a normal frequency distribution curve.

In an effort to correlate IPD with the Ortho-Rater test for far lateral phoria, 115 men were measured on the NDRC Interpupillometer, the Ortho-Rater, and the Maddox Screen test for far lateral phoria.

SUMMARY OF EXPERIMENTAL RESULTS

No correlation is apparent between the IPD and the results on the Ortho-Rater test for far lateral phoria, for either the whole group or a part of the group consisting of the extreme wide and narrow IPD's.

In addition, the IPD's were plotted against the results for the maddox screen test for far lateral phoria, and again no correlation appears.

In the interest of strict accuracy in comparison of tests, it should be stated that identical ocular functions are measured only when the tests used employ the same test principle or combination of these. Thus, if the Ortho-Rater test for lateral phoria is compared with another test for lateral phoria, the results are strictly comparable only if the other test employs identical principles - in this case, distortion and displacement with a slight fusional aid. These conditions are not met, for example, if the Ortho-Rater test is compared to a test which employs the cover test principle, such as the screen and parallax test.

Again, in the interest of strict accuracy, a comparison of the results of tests conducted at different distances involves factors inherent in the nature of binocular fixation. It is doubtful, therefore, that tests of lateral muscle imbalance which are conducted at a distance of 20 feet measure identical ocular functions as do similar tests applied by means of instrumental screening devices. This does not mean that such screening devices are inaccurate, since it is emphasized that instruments measure definite muscular functions even if such functions are not the identical ones determined at an actual 20 foot distance. Also, any error introduced by the use of decentered convex lenses is at least not greater than about one prism diopter. This compares favorably with the variance found in a comparison of test-retest results using conventional methods for determination of muscle balance.

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11. COMPARISON OF BINOCULAR AND MONOCULAR VIEWING OF TESTS FOR MONOCULAR ACUITY ON THE ORTHO-RATER

Lt. Dean Farnsworth

The Bausch & Lomb Ortho-Rater uses a technique for testing visual acuity in which both eyes remain open and see corresponding images -- except for one portion of each test object. Thus a checker board is superimposed binocularly upon a uniform gray square of the same size seen with the other eye. The observer ordinarily is not aware which eye is viewing the checker board and which the gray square.

The question has been raised as to whether retinal rivalry between the images of the two dissimilar test targets impairs the efficiency of the test.

One hundred men were tested and retested in the usual manner with the targets visible to both eyes simultaneously, and tested and retested with the right and with left eye while the non-significant target was occluded from the other eye. (The latter situation corresponds to the usual clinical test in which the eye not being tested is covered.) In the latter situation the observer was told, "We are now testing your right (left) eye." The tests were given in a predetermined random order.

Naval personnel were used for observers. Scores for visual acuity were recorded in 0.1 intervals (equal to the difference of 20/20 and 20/19). Pearson coefficients of correlation were determined for scores reported on the left eye tests.

1. Test-retest
   Targets presented to both eyes $r = .70$

2. Test-retest
   Target presented to left eye $r = .63$

3. Correlation of first tests,
   (1) and (2). $r = .74$

4. Coefficient in (3) corrected
   for imperfect reliability of
   the tests

$$= \frac{.74}{\sqrt{.63 \times .70}} = R_{12} = 1.1$$

The mean score for condition (1) is the same as for condition (2), and the distributions of scores are apparently the same.

Furthermore, since R_{12} is greater than 1, there is no statistical indication from this experiment that binocular presentation of the targets introduces a factor of unreliability in the Ortho-Rater test for monocular acuity.

Considering the homogeneity of the population, the results are interpreted as having satisfactory reliability.

Discussion:

Lt. Comdr. Peckham pointed out that because of the limited reliability of the Ortho-Rater, this study can not be considered to establish that the manner of occlusion is not a factor in measuring acuity. Although occlusion is not a variable in the present instrument, a more precise measurement of acuity might detect the influence of the occlusion factor.

Dr. Hecht stated that the problem is not one of the effect of the use of an occluder as opposed to no occluder. A blank patterned field at the testing distance, the condition provided for the other eye in the standard Ortho-Rater presentation, has the effect of an occluder on the retina. The problem is one of selecting the kind of occluder that will least affect the results of the test.

Dr. Marquis pointed out that the experiment reported by Lt. Farnsworth showed that a black, near occluder has no perceptibly different effect from the blank test object and stressed the need for a study of the effect of various occluding brightnesses on test performance.

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SUPPLEMENT TO

MINUTES AND PROCEEDINGS

of the

ARMY-NAVY-O S R D

VISION COMMITTEE

TWELFTH MEETING - 12 JUNE 1945

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SUPPLEMENT
to

M I N U T E S   A N D   P R O C E E D I N G S

of the twelfth meeting of the

ARMY - NAVY - OSRD VISION COMMITTEE

12 June 1945

National Academy of Sciences
Washington, D. C.

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U.S. Armed Forces—NRC Vision
Committee

2. DICHROMATIC TRACER DETECTION FILTER

Lt. Comdr. R. H. Peckham

It was previously reported to this committee (Proceedings, eleventh meeting, pp. 65-72) that the spectrographic analysis of tracer fire indicated a filter with high transmission in the blue, absorption in yellow-green, and high transmission in red. Such a filter has been developed in accordance with this suggestion by the Polaroid Corporation. The spectral transmission curve is shown in Figure 1. The filter is amber in appearance and contains a polarizing element. Because of its peculiar dichromatism, the filter is expected to be especially useful in detecting tracer fire.

Field tests with this filter for the purpose of determining its usefulness in identification, camouflage detection, location of objects on the surface of water, air-sea rescue and similar problems was undertaken in Pensacola. The filters were used by the author both in an airplane performing a typical air-sea rescue search problem and aboard a liferaft in watching for air assistance. Eight filters were provided for the experiment; three enlisted men and four officers assisted in the tests.

The filter was found to be extremely useful in locating yellow liferafts on the surface of the water, due to the fact that the yellow was rendered a bright, flame orange color, and the water, by virtue of the polarizer, was rendered nearly black, thus creating a high contrast in both brightness and color. The green fluorescent dye marker was discovered to stand out at high color and brightness contrast with respect to sea water. The red smoke signal was found to be visible at greater ranges, and red flares of the Very pistol type were more easily located using the filter. The measurement of ranges was not practical on this preliminary experiment, but estimates of various objects would indicate that range was increased in some cases by a factor as great as five times and in others by a factor at least as great as one and one-half.

The brightness of the filter is such that it acts as a successful sunglass, transmitting less than 10% of the light and, thus, tending to preserve dark adaptation. The rod transmission of this filter is 4.0% and the cone transmission is 4.2%, indicating that there is no significant increase in the preservation of rod function over the visual stimulus provided in the daytime.

The filter was tried in both the brow-rest type of sunglass and in the M-1944 Aviation Goggle. It was equally successful in either form and is especially recommended in the sunglass form

since the sunglass is so light and convenient to use. Development is underway in preparing a brow-rest type of sunglass with removable lenses so that such a filter may be used in a sunglass kit of interchangeable lenses.

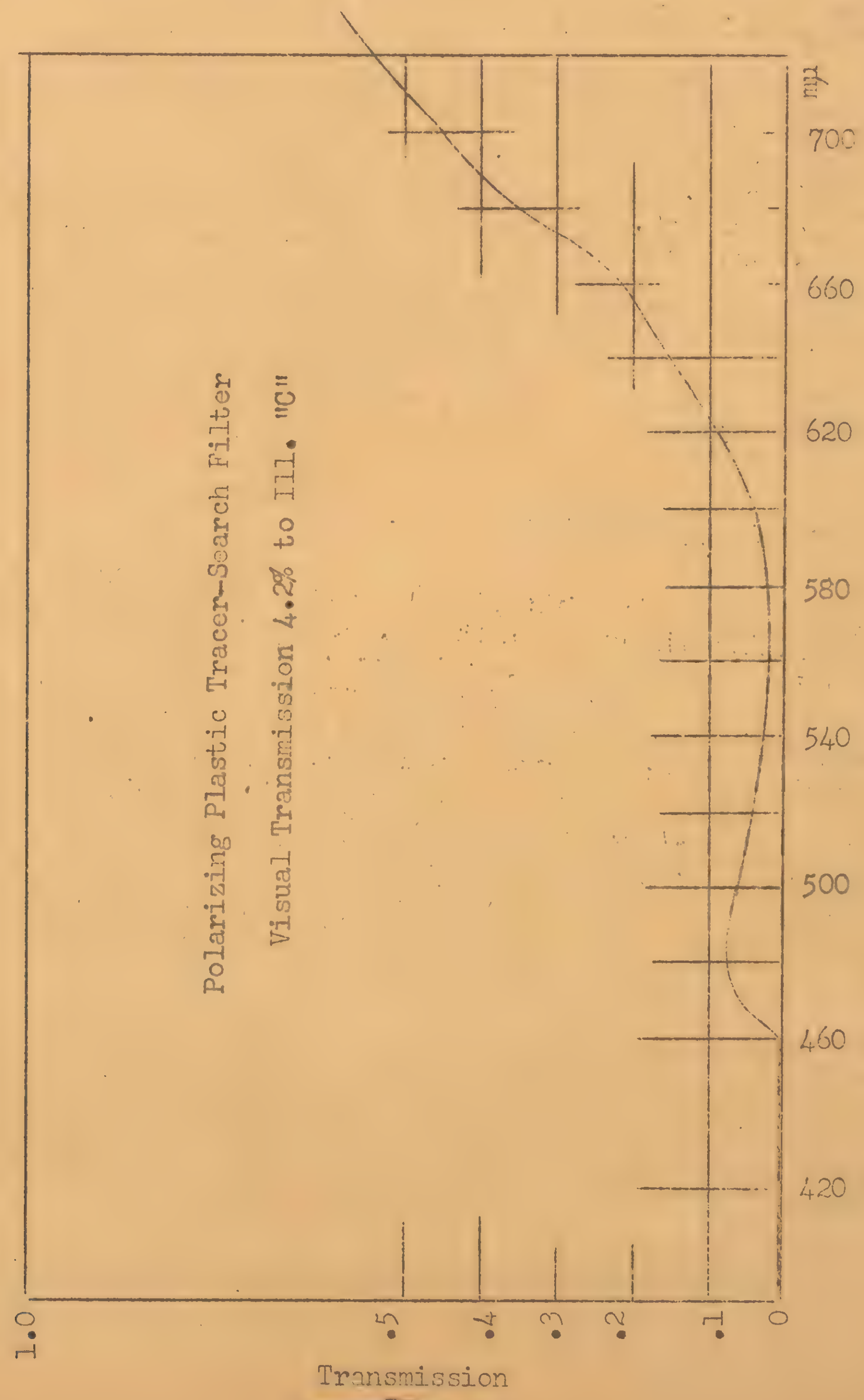

Figure I

8D. VISUAL ACUITY AND CONTRAST DISCRIMINATION THROUGH NEUTRAL AND COLOR FILTERS

Lt. (jg) W. S. Verplanck

"NEUTRAL" FILTERS

Data on both visual acuity and brightness discrimination indicate that the effect of a neutral filter of good optical quality can be directly predicted by its density, and by the sky brightness under which it will be used. According to these data, neutral filters may be employed without serious deficit in visual acuity or brightness discrimination, provided that the product of sky brightness and the photopic transmission factor of the filter is not less than 10 millilamberts. If the product is 100 ml., no loss should be demonstrable.

There are, however, three lines of evidence that this conclusion may not be accepted without further study in the field.

1. Although sky brightness may be sufficiently high to indicate that the use of a particular neutral filter will lead to no deficit in visual acuity or contrast discrimination of targets appearing against the sky, the brightness of other parts of the visual field, e. g., of objects in shadows, may be reduced sufficiently to render such objects subliminal.

2. Data verbally transmitted by Dr. Simon Shlaer of Columbia University indicate that the discrimination of targets of minimal size (.5 x 1.0 min.) may improve with an increase in brightness beyond the 100 millilamberts value cited above. Consequently, a goggle which does not interfere with visual acuity or contrast discrimination as usually defined at usual sky brightnesses, may nevertheless render invisible targets of minimal area, such as distant planes.

3. Field data* on the vanishing ranges of aircraft, obtained under sky brightnesses up to 2,000 ml., show losses in range of sightning proportional to the density of the neutral filter used, even though a neutral glass of density-1.30 log units might have been expected to lead to no deficit. Even a "transparent" filter produced loss of range. This finding is not out of harmony with (b) above.

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* Gt. Brit., AORG Memorandum No. 69, 3 May 1943, 8 pp.

COLOR FILTERS

Any color filter will enhance the contrast of certain colored targets, and decrease that of others, depending on the filter used and the targets and backgrounds observed. Filters cutting off the violet end of the spectrum might be expected to permit "haze penetration," so that the contrast of distant targets, desaturated with respect to color, might be improved.

Color filters and neutral short range targets

Two studies over short ranges indicate that, when the objects to be discriminated are acuity figures characterized by brightness contrast only, e. g., a set of black acuity figures on a white backgound, or a grating acuity test object, the overall photopic transmission factor is more critical than the transmission for any given set of wavelengths. One set of data*, obtained with a Lumarith green 0-4403 plastic filter of photopic density-0.72 log units shows results which are of the same order of magnitude as those which would be produced by a brightness decrease of approximately 1.0 to 1.2 log units. The difference between 0.72 and 1.0 - 1.2 may be accounted for by poor optical properties of the plastic; it represents a not inconsiderable loss. Data** on the grating show a loss of acuity more closely related to the transmission of the several filters employed, which were of several colors. These data, however, lack statistical reliability. The former data, it should be noted, confirm the expectancy in the first paragraph above.

Color filters and haze penetration

There is not abundant evidence on the ability of any filter designed for visual use to improve the contrast of distant targets.

1. The Kodak Research Laboratory*** has reported measurements of brightness contrast at the horizon (sky-sea ratio) which indicate that a Wratten No. 29 filter, and a yellow filter of Russian manufacture may increase this contrast. Polaroid plastic was also found to increase contrast under certain conditions. No targets were observed in these studies.

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* Beebe-Center, J. G., Carmichael, L., and Mead, L. C., Daylight Training of Pilots for Night Flying, Aeronautical Engineering Review, Vol. 3, pp. 1-10, 1944 (November)

** Gt. Brit., Admiralty Research Laboratory., Acuity of Vision Through Color Filters, ARL/N8/0360, March 1943, 5 pp.

*** Gt. Brit., Kodak ltd. Research Laboratory, Harrow. Report No. H1191, 14 October 1945, 12pp.

2. The AORG report cited above, indicates that, although the use of a red filter of 10-15% transmission did not increase the range at which aircraft could be detected, it did yield maximum ranges of the same order of magnitude as those obtained with the naked eye, even though a measurable loss was obtained with neutral filters of higher transmission and with filters of other colors of the same photopic transmission.

GENERAL REMARKS

The results cited do not provide a sufficient basis for drawing conclusions. There is the interesting suggestion that goggles similar to red dark adaptation goggles might be satisfactory for protection of the eyes from the long-lasting effects of exposure to sunlight on dark adaptation with minimal loss of acuity and contrast discrimination - at the cost of complete loss of color discrimination.

By and large, the following questions are still unanswered:

1. Can the prediction from laboratory data that sunglasses or goggles may be worn on all but the darkest days without impairment of visual acuity or brightness discrimination be verified in a field test?

2. Can a filter be produced which will so reduce the effects of scattered light that the contrast of distant objects (and consequently the range at which they may be detected) will be increased?

ABSTRACTS

81. A COMPARATIVE TEST OF RETICLE PATTERNS FOR THE GUN SIGHT MARK 15

Birmingham, H. P., T. G. Hermans, A. S. Householder, W. E. Kappauf, H. D. Meyer, F. V. Taylor, National Defense Research Committee, Applied Psychology Panel. Project N-111, Report No. 3, Contract OEMsr-815, OSRD Report No. 4878, March 30, 1945, 13 pp. (Confidential)

This report presents an evaluation of three reticle patterns which have been tested in the Gun Sight Mark 15. The patterns were: No. 1, a circle 15 mils in diameter (the present standard gun sight reticle); No. 2, a pair of crosslines; No. 3, a set of 3 concentric, dashed circles, 3, 9, and 15 mils in diameter, with solid crosslines extending outward from the 15 mil circle.

Four tests were carried out under several different tracking conditions. In the first test, tracking accuracy was greatest with Reticle No. 3. In the other three tests, tracking accuracy was greater with both Reticles No. 2 and No. 3 than with No. 1. It is believed that this difference results from the fact that Reticles No. 2 and No. 3 define the reticle center on the point of aim more accurately.

Because Reticle No. 3 is superior to No. 1 for tracking purposes, and superior to No. 2 when considered for its usefulness in facilitating check sight scoring on the Gun Sight Mark for general use. This recommended reticle would have a 3 mil circle and a 15 mil circle. Crosslines extending outward from the 15 mil circle or special interruptions in the circles might be used to indicate the vertical and horizontal axes of the field of view.

82. CONFERENCE OF FLYING SUN GLASS, SPECIFICATION AN-G-22.

Hqs. Air Technical Service Command. Aero Medical Laboratory. TSEAL 3-695-47E. June 14, 1945, 3 pp. (open)

A conference of sun glass manufacturers and ATSC personnel

was held to discuss changes necessary in Specification AN-G-22 in order to attain standardization and interchangeability of parts of all manufacturers of this item. The changes necessary were presented to the manufacturers and these manufacturers will report to the ATSC concerning the best methods of obtaining this standardization.

The report recommends that upon receipt of sun glass manufacturers report steps be taken by ATSC to effect changes in Specification AN-G-22 which will result in the standardization and interchangeability of parts of the Flying Sun Glass.

83. INSRUMENT-PANEL LIGHTING IN MODEL TBM-3, BuNo 23013, AIRPLANE - INVESTIGATION OF.

Naval Air Station, Patuxant River, Md. Radio Test. Project No. PTR 31826.0, April 27, 1945, 7 pp. (Restricted)

A photograph of the TBM-3 instrument cover-panel showed glare spots caused by lower section of the cutout flanges an uneven illumination of the instruments. An experimental panel incorporating modifications in the flanges and instrument lighting was worked out and photographed; most of the glare spots were removed. The report recommends that present panels be modified and production airplanes be changed to provide better instrument lighting. The report includes adequate notes on necessary changes to make a modified instrument panel for the TBM-3 airplane.

84. REPORT OF TESTS OF GOGGLE, M-1944 GLASSES, SUN COMPARATIVE TEST OF SUN GLASSES AND GOGGLES

Army Service Force. The Quartermaster Board, Camp Lee, Va. Quartermaster Board Projects T-425, T-447, and T-455. March 31, 1945, 42 pp. (open)

Extensive tests comparing

a. 24 each, Goggle, M-1944 (Type 1), standard clear and green uncoated lenses - Marked "A"

b. 24 each, Goggle, M-1944 (Type 2), Coated lenses - Marked "B"

c. 24 each, Goggle, M-1944 (Type 3), Coated lenses - Marked "C"

d. 25 each, Goggle, M-1943 (Type 1), Clear lenses

e. 25 each, Goggle, M-1943 (Type 2), Green lenses

f. 25 each, Goggle, M-1943 (Type 3), Red lenses

g. 25 each, Goggle, Dust, German (Type 1), Clear lenses

h. 25 each, Goggle, Dust, German (Type 2), Green lenses

i. 20 each, Glasses, Sun, M-1944, JQD 597, (Type 1)

j. 20 each, Glasses, Sun, Spectacle type, JQD 206C, (Type 2) Commercial type.

k. 15 each, Glasses, Sun, F-1 AAF 3204, (Type 3)

l. 12 each, Glasses, Sun, Clip-on Type, JQD 206C (Type 4A), Commercial Type with metal frame

m. 8 each, Glasses, Sun, Clip-on Type, JQD 206C (Type 4B), Commercial Type with plastic frame

n. 24 each, Eyeshields, M-1 (CWS), Clear

were conducted by the Quartermaster Board. The tests were devised to evaluate adequacy of fit; interference caused by various types of headgear; field of vision; effect on color perception; effect on visual acuity; protection against glare; general stability and protection against wind; susceptibility of lenses to fogging; bulk, protective features, and relative convenience of carrying methods of the cases; scratch resistant propoerties; effect of weathering; and strength.

Results of the tests are included in the report, and comparative evaluations made for each of the characteristics tested. The findings support the following recommendations:

1. The Goggles M-1944 be considered superior to the other goggles tested but that the following modifications be adopted:

Lenses to be coated similar to those of the M-1944

goggles, Types 2 and 3.

b. Lenses to be a green color.

c. Provision for increased ventilation to prevent fogging.

2. The glasses, sun, F-1, AAF 3204 (Type 3) be considered superior to the glasses, sun, M-1944 (Type 1), and the glasses, sun, spectacle type, JQD 206C (Type 2) be considered inferior to the other spectacle types.

3. The glasses sun, clip-on, JQD 206C (Type 4B) be considered slightly superior to the clip-on Type 4A glasses and superior to the glasses, sun M-1944 (Type 1) for use with government issue opthalmic glasses.

4. Troops issued the eyeshield, M-1 be authorized to use this eyeshield for protecting the eyes from dust when severe conditions are encountered and goggles are not available.

5. A sufficiently re-inforced case be provided with the clip-on type sun glasses to prevent frequent bending of the clips.

6. Consideration be given to conducting further tests of the items recommended above together with suitable items of comparison under actual conditions of dust and glare to determine the comparative suitability of each under these conditions.

85. A HAND-HELD INSTRUMENT FOR MEASURING VISUAL FIELDS FROM AIRCRAFT

Hqs. Air Technical Service Command. Aero Medical Laboratory. TSEAL-3-695-48C, April 11, 1945, 9 pp. (open).

A small hand-held theodolite was designed to meet the requirements of a study of visual fields from military aircraft enclosures. This instrument provides a means for measuring vertical or horizontal angles at the eye without a fixed viewing point. Since neither a stable, rigid base, nor a fixed levelling device are required, as in a standard surveyor's theodolite, this instrument may be held in the hands and moved freely with the body. Thus, it may be used for measuring functional visual fields from any desired position in an aircraft, (e. g., nose, tail, waist), through the normal range of body movement characteristic of the combat requirements of each position. A complete description of this instrument forms an appendix to the report.

A study of the consistency of measurements made with this instrument indicates that visual fields measured with it by any one individual vary little from day to day, whereas visual fields measured by different individuals tend to differ reliably. Comparisons of the fields of view from several different aircraft should, therefore, be made on the basis of one individual's measurements, or those of a large number of individuals. The complete data of this study will be presented in a forthcoming memorandum report.

86. RETROREFLECTIVE MATERIAL, NIGHT VISUAL RANGES

Kelly, D. H., and H. F. Cross. Naval Air Station, Patuxent River, Md. Tactical Testi Project TED. No. PTR-2570.1. April 7, 1945, 3 pp. (Restricted)

(1) Aluminum sheet, polymerized in plastic, (2) Evaporated aluminum backed, (3) Scotchlite (most efficient type), (4) Fluorescent backed, materials under consideration as air-sea rescue aids, were tested for maximum visual ranges outdoors on a clear, moonless night. Samples 1 and 2 are nearly equal in effectiveness; both are much more efficient than 3 and 4. It is recommended that either aluminum sheet polymerized in plastic, or evaporated aluminum backed material be adopted as the most efficient of the rescue devices tested.

87. REPORT ON DAZZLING EFFECTS OF REFLECTED SUNLIGHT

Hulburt, E. O. Naval Research Laboratory. Report No. H-2494. April 12, 1945. 20 pp. (Confidential)

The dazzling effects on observers on the ground in the beam of sunlight reflected from a mirror and of a 60 inch Army searchlight were observed on clear sunny days. For unaided eyes the angular radius θ of the dazzle obscuration was about 5° at 200 yards from the searchlight; θ varied inversely with the distance and directly with the square root of the candle power of the searchlight. In clear sunny weather with the mirror approximately normal to the sun's rays the illumination of the sunlight reflected from a 2.5 feet diameter mirror was about the same as that from the searchlight. For the mirror θ varied inversely with the distance and directly with the diameter.

Observations with a Mark 8 gunsight and a Japanese torpedo sight indicated that the dazzle from the searchlight or mirror

probably would not interfere with the use of these instruments until the distance became less than 1000 feet.

The conclusion was reached that the use of the searchlight or reflected sunlight was of doubtful value against attacking aircraft. Hence full scale experiments with airplanes in flight were not recommended. It was admitted that such experiments are necessary to determine the correctness of the conclusion. Because full scale experiments might give data on certain elements not touched upon in the present experiments, such as surprise, confusion and deception of the dazzlee into thinking that the light beam was something worse than it really was.

88. THE COURSE OF DARK ADAPTATION AFTER WEARING ORANGE DARK ADAPTOR GOGGLES

Clark, W. B., and M. L. Johnson. U. S. Naval Air Training Bases., Naval School of Aviation Medicine, Pensacola, Fla. Project X-439 (Av-230-p), Report No. 1, February 19, 1945, 13 pp. (open)

In an attempt to find a substitute for the standard Navy Red Dark Adaptor Goggles which will permit color perception and at the same time effectively protect dark adaptation, the course of dark adaptation was determined in eight previously dark adapted subjects following their exposure to room illumination for periods of 5, 10, and 15 minutes while wearing 50% transmission and 5% transmission Orange Dark Adaptor Goggles. The course of dark adaptation in the eight subjects was also traced following exposure to room illumination for 5, 10, and 15 minutes while wearing 5% and 10% transmission neutral goggles.

The 50% orange goggles are of no practical value in protecting dark adaptation. The standard red goggles are markedly superior to the 5% transmission orange goggles and to the 5% and 10% neutral goggles under conditions demanding recovery of the completely dark adapted state within a very few minutes after exposure to room illumination.

Under conditions requiring the recovery of a somewhat less completely dark adapted state within 4 minutes after exposure to light, the 5% orange goggles have been found to be almost as effecient as the standard red goggles. The 5% and 10% neutral goggles under these conditions are inferior to both the 5% orange and the red goggles.

In the absence of definite knowledge regarding the conditions of illumination and the visual tasks to be performed in various field situations, it is difficult to determine accurately

the practicability of the various goggles tested. Appropriate field tests should be made to determine what degree of dark adaptation is required for effective vision under illuminations obtaining in operational conditions before a definite evaluation of these goggles can be made.

89. DEPTH PERCEPTION THROUGH THE B-8 GOGGLE.

Schachter, Stanley. Hqs. Air Technical Service Command. Aero Medical Laboratory. TSEAL 3-695-47D. May 31, 1945, 4 pp. (open)

Six subjects were each given ten trials on the Harvard-Dolman apparatus while wearing the B-8 goggle with (1)green and (2) amber plastic lenses and a sun glass with neutral green lenses; ten trials were given while wearing no goggle at all. Depth perception as measured by the H-D apparatus is not impaired by looking through any of these lenses.

90. THE EFFECT OF THE NAVY AIRBORNE SEARCHLIGHT ON DARK ADAPTATION

Orlansky, J. Medical Department. Naval Air Station, Quonset Pt., R. I. Project X-503 (Av. 270-p), Report 1. May 2, 1945, 9 pp. (Confidential)

This study measured the time of recovery of dark adaptation following exposure to the airborne searchlight, carried by planes to produce an intense illumination upon a target, under flight conditions. Dark adaptation was charted, using the Wald adaptometer, on each of 174 searchlight runs (17 night flights). Readings were taken as rapidly as possible after exposure to the light and until the level existing before the run was again reached. The average recovery time was 21.5 seconds, with a range, as measured by the average for any one night, from 13.6 to 31.2 seconds. The average increase in light threshold was 0.49 log units. Variables influencing the results were relatively high brightness in the cockpit, the length of exposure to the searchlight beam, and atmospheric conditions.